This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Michigan technic

University of Michigan Engineering Society, University of Michigan. College of Engineering, University of Michigan. College of ...

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

THE MICHIGAN TECHNIC

VOL. XXVIII
NUMBER 1

ANN ARBOR, MICH.
MAY, 1914

PRICE 25c
SUB. YEAR, $1.00

TABLE OF CONTENTS

Letter to Alumni. *Dean Cooley*..... 3
Chas. S. Denison, Memorial. *Prof. H. J. Goulding*..... 5
Photo of New Power Plant to accompany Article..... 8
The Hingeless Elastic Arch. *F. A. Steiger*..... 9
Practical Applications of Logarithmic Paper. *W. F. Verner*, M.E..... 20
The Use of Groins for Shore Protection. *R. R. Tinkham*..... 30
The Gyroscope in Stabilizing Problems. *J. Airey*, D.I.C..... 42
The Experimental Refrigeration Plant. *H. E. Keeler*, '12E..... 55
An Automatic Headgate. *Karl F. Keeler*, '15E..... 62
The New Power Plant. *H. I. Markey*..... 70
Editorials 75
Alumni Notes 79
Departmental Notes 85
Collecting Class Pictures.
New Automobile Engineering Courses.
New Laboratory Equipment.
General Index of All Articles since 1886.....92
Index to Advertisers .....Inside Back Cover

Digitized by Google

A TWO-CENT STAMP
AND
A ONE DOLLAR BILL

And you will receive The Michigan Technic in October and December, 1914, and March and May, 1915.

Read the editorials relative to the Technic and Engineering Society.

The Technic is the only strand of connection between the Alumni and the Faculty and Students of the Engineering Department.

Your subscription is needed, and you need The Technic.

Write to

THE MICHIGAN TECHNIC

Old Engineering Building Ann Arbor, Michigan

Digitized by Google

VOL. XXVII MAY, 1914 No. 1

THE NEW YORK
PUBLIC LIBRARY
374264A
ASTOR, LENOX AND
TILDEN FOUNDATIONS
R 1928 L

THE MICHIGAN TECHNIC

OFFICIAL ORGAN OF THE

ENGINEERING DEPARTMENT

PUBLISHED QUARTERLY

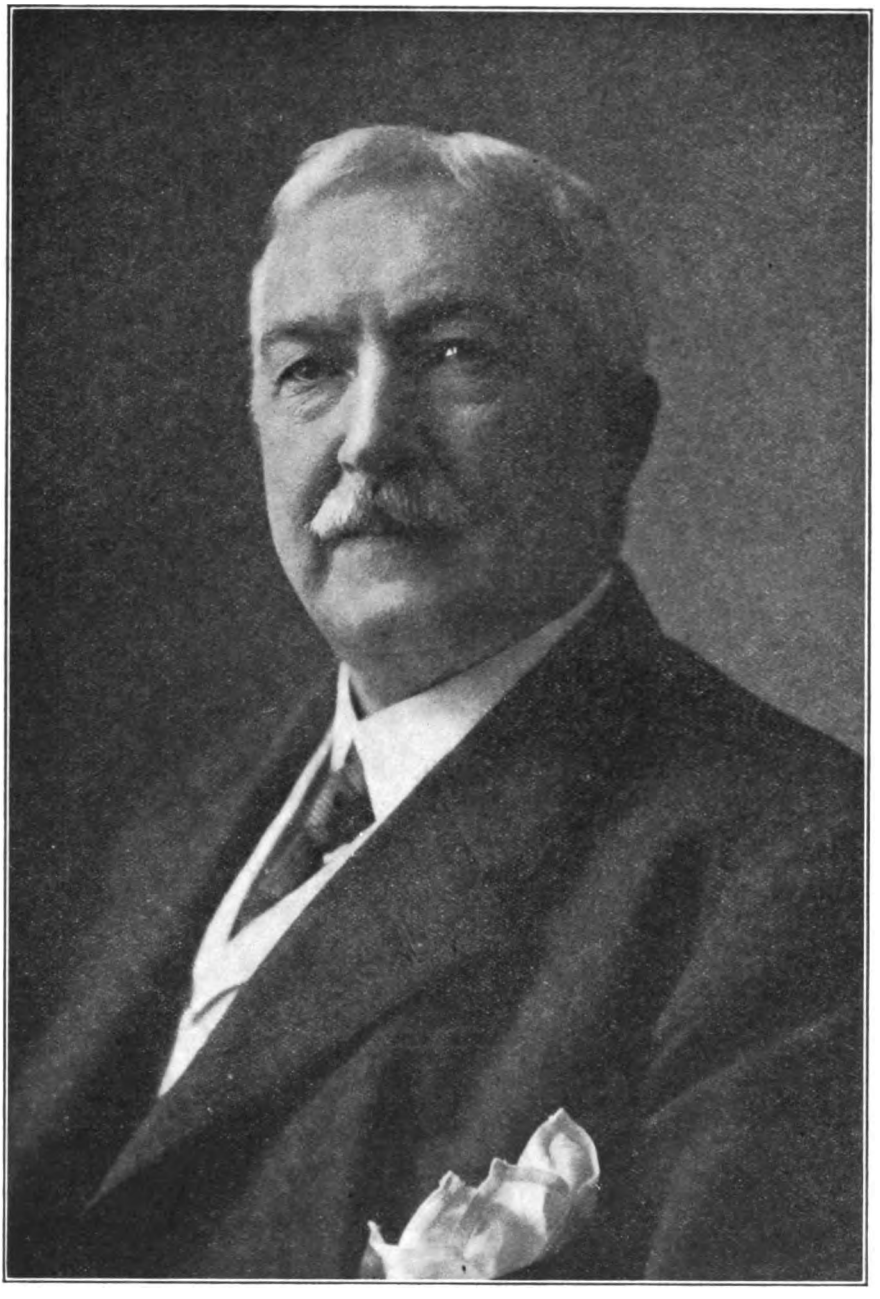
BY THE

ENGINEERING SOCIETY
(INCORPORATED)

UNIVERSITY OF MICHIGAN

TWO THOUSAND COPIES
PRICE 25 CENTS
SUBSCRIPTION, $1.00 PER YEAR

Digitized by Google



MORTIMER E. COOLEY

NEW YORK
PUBLIC
LIBRARY

Digitized by Google

THE MICHIGAN TECHNIC

DEAN COOLEY

The Engineering Society was started back in the middle eighties, and almost immediately became prominent in the affairs of the Department. One of its earliest activities was a non-resident lecture course. Desiring to preserve in printed form some of the lectures, there were published in 1886, and for three years after, a few each year under the title of "Selected Papers." From this small beginning sprang the more imposing annual known for a number of years as the "Technic" and later as the "Michigan Technic."

The success of this annual was such that it was sought in exchange by state engineering societies, and for many years each subscriber of the Technic received the publication of a number of other societies without addtonal expense. The Technic was sought by public libraries, and its articles were freely copied in the technical journals. It constituted in some measure the medium through which the results of original investigation in the Department were made public It differed from most other college publications in the respect that it was wholly con ducted and managed by students without faculty control or financial support outside of the Engineering Society. Its space was sought by advertisers, and to such extent that it was possible to include the Technic in the annual fee of one dollar charged to all members of the Society.

Desiring to increase its usefulness the annual was changed to a semi-annual with even greater success, and then a few years ago to a quarterly. But in making this last change the management did not forsee, or did not realize, the great amount of time required, time which could not well be spared by students from their studies, particularly as the requirements for graduation had been greatly increased from 120 hours to 140 hours. Troubles began and multiplied to such an extent that teh new venture proved more or less disastrous. A debt was incurred, which at one time amounted to $500 or $600. But this was carried by the Engineering Society, and efforts were renewed with vigor by succeeding Boadrs to put the Technic back on its feet. Their success was such that the debt was paid off and a small sum turned into the treasury of the Society.

Flushed with victory ambition was again let loose, this time in an attempt to publish the Technic as a monthly, but still without other aid than could be given by the Society. Desiring, however, to make some use of the monthly in the English classes, the part time of one of the English instructors was given in a supervisory way to the editorial work. Again reverses were encountered, largely due to inexperience, lack of advertising patronage, and a sufficient number of articles to fill its pages. It was really too much to ask of students in addition to their

Digitized by Google

other work, and faculty members were too busy to aid greatly.

This year the entire matter was referred to a joint committee of student and faculty members for investigation and report. The result is a new Michigan Technic, this the first number being offered you as a forecast of its future. It has been attempted to incorporate in it the successful features of earlier Technics, avoiding the pitfalls of later years, and it is confidently expected that the plan elsewhere described will prove successful.

One of the main features of the new plan is the reorganization of the Engineering Society to embrace branches in civil, mechanical, electrical and chemical engineering. As of old non-resident lecturers will appear under its auspices. Each member will be entitled to receive the Technic as a part of his dues which go to its support. This insures a large circulation on the Campus. With the friendly attitude of the large body of engineering alumni, its success financially seems assured. The plan has been approved by the Standing Committee of the Department,and the faculty members of the board of management have been selected with special reference to their fitness for the work. This year's single issue will be followed next year with three or four issues. It is hoped to make the Technic a direct means of communication between those of us holding the fort here and those out on the firing line. It is intended to prove worthy of the hearty support of every alumnus, to the end that his cordial interest and support will be enlisted without special solicitation.

Digitized by Google

CHARLES SIMEON DENISON

In the death of Professor Charles Simeon Denison, the University of Michigan lost a member of its Department of Engineering faculty who has been aptly characterized by Dean Cooley as "a modest man, a gentle man, a dignified man, a proud man, a zealous man. He was zealous in the interests of the Department; proud of its achievements; dignified in his resentment of any acts considered by him presumptous; gentle in expressing his resentment; and modest fearing he might have gone too far in the censure he intended."

Dr. Angell, his life long friend and admirer, said of him at the time of his death: "He was a good man, and he came of a long line of good men." Of this "long line of good men" he had every reason to be proud. The family traces its lineage from Antenor, King of the Cimbri, of the Trojan nobility, born about 1239 B. C., down through Charlemagne and a royal line to Captain George Denison of Stonington, Connecticut, who came to America in 1631, and who achieved distinction for services rendered in Cromwell's army and in our own Indian wars.

His grandfather, Dr. Joseph A. Denison, was a noted physician. His grandmother, Rachel Chase, was a sister of Bishop Philander Chase, and of U. S. Senator Dudley Chase.

His father, the Reverend George Denison, an Episcopal clergyman, was a graduate of Kenyon College, a Protestant Episcopal School located at Gambier, Ohio, where later he became professor of Mathematics after having taken a post graduate course in mathematics at Yale. His mother was Janet Ballock Ralston, a descendant of the Ralstons of Falkirk, Scotland.

Charles Simeon Denison was born at Gambier, Ohio, July 12, 1849. When he was four years old his father resigned his professorship at Kenyon College and accepted a call to St. Johns Episcopal Church at Keokuk, Iowa. In this place beautifully situated on the bluffs overlooking the Mississippi were spent the next eight years of his life, at the end of which time his father died. His mother then returned to Lockport, New York, with her family and here from the age of 12 to 18 he received an excellent preparation for a classical collegiate course.

While a young boy he exhibited skill to a remarkable degree in the construction of his toys. At the age of ten he built a locomotive with a train of cars and a track that were the envy of his playmates. Soon after his return to Lockport he made a small stationary engine of metal together with a boiler. This engine attracted the attention of the head manager of one of the local manufacturing establishments who had the machinery stopped for a few minutes while the engineer

Digitized by Google

and workmen gathered around to see the little engine run by steam from the big plant. While still a school boy he made drawings for a rotary engine. He had never seen one and was much disappointed to learn he was not the first in the field.

He was obliged to leave his school work for a time on account of ill health brought about by too close an application to his studies and the lack of proper exercise. The outdoor work on local surveys to which he devoted himself built up his health, and the experience gained, together with his natural mechanical ability, influenced him in his decision to adopt engineering as his profession.

At the age of 18 he entered the Norwich University, a military school located at Northfield, Vermont, where he remained one year. He then went to the University of Vermont at Burlington, entering as a sophomore. Dr. Angell, who was then president, made him adjutant of a company in military drill. In 1870 he received the degree of Bachelor of Science and in 1871 the degree of Civil Engineer. His Alma Mater also conferred upon him the degree of Master of Science in 1874, and the honorary degree of Doctor of Science in 1907.

While at Norwich University he joined Theta Chi, and upon entering the University of Vermont he became affiliated with Sigma Phi. Later he became identified with the American Society of Mechanical Engineers, the Society for the Promotion of Engineering Education, the Michigan Engineering Society and the Ann Arbor Scientific Society, now the University of Scientific Club. He was also an honorary member of the students' Engineering Society of the University of Michigan and of Tau Beta Pi.

His first practical experience after taking his degree of Civil Engineer was gained with the Milwaukee and Northern Railway in Wisconsin, where he was engaged in making the survey of a line from Milwaukee to Green Bay. He remained at this work until March or April of 1872, when he was called to the University of Michigan as instructor in Engineering and Drawing, by James B. Angell, who had assumed the duties of president in 1871. He rose through the several grades to the professorship of Descriptive Geometry, Stereotomy and Drawing, which was given him in 1885. In 1901 the Board of Regents changed his title to that of Professor of Stereotomy, Mechanism and Drawing. This title he held until his death, which occurred at his bachelor quarters in Ann Arbor, Michigan, on Wednesday, the 30th of July, 1913. He is buried with his father and mother, at Keokuk, Iowa.

At the close of his first year at the University of Michigan he was engaged with Rollin J. Reeves to survey the boundary line between the territories of Idaho and Washington from the Snake river north to the national boundary. This proved to be a very hazardous undertaking and nearly cost the entire party their lives. The last fifteen miles of this survey were run on flour diet. Thirty-five years later a resurvey

Digitized by Google

was made of this boundary. In their report of this survey the men engaged say: "With the knowledge of the country traversed, as it is today, one can but marvel at the persistence and hardihood of that party of men who did not falter until actual lack of food compelled retreat."

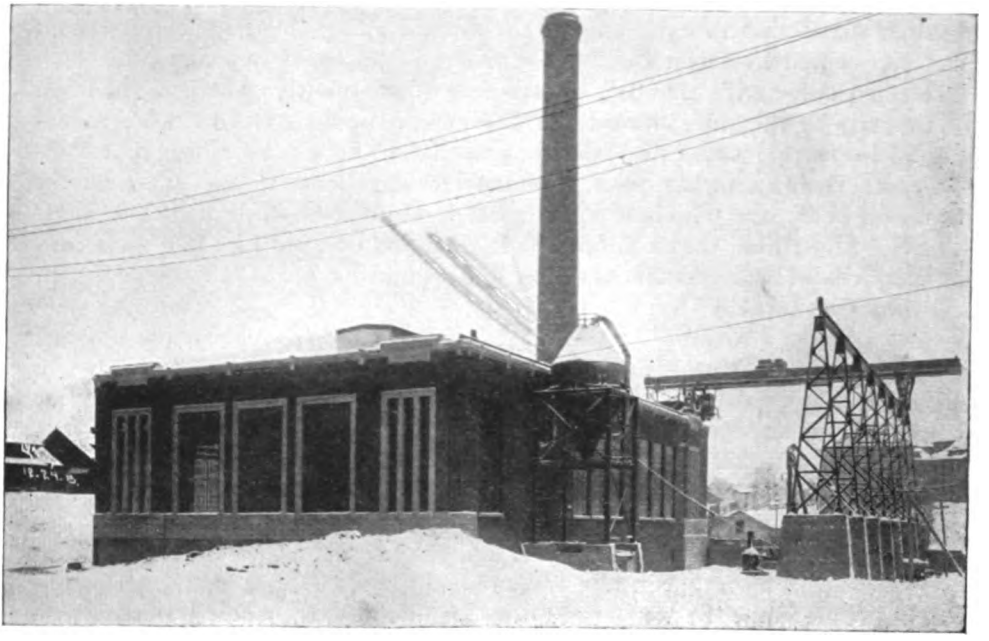
Throughout his 41 years of service as a teacher he became endeared to his colleagues and students alike by reason of his noble and generous disposition, his kindly feeling for all, and his sympathetic nature shown in his solicitation for the welfare of others. His uniformly just treatment of his students in all his dealings with them, and his eminently fair criticisms so skillfully given could hardly leave any other impression than that found to exist among the alumni along the Pacific coast who were visited by Dean Cooley, Dean Reed and Secretary Shaw in 1909. Dean Cooley says that the question most frequently asked of them on this trip by the older alumni was "Tell us of the little Lord Chesterfield," and he further says: "I knew then, as I had believed before, that Professor Denison in his quiet, unobtrusive way, had stamped his character on every one who had come under his influence while in the University. Something that was pure and sweet and good in him had gone into the lives of these students, these old alumni, who asked: "Tell us of Lord Chesterfield."

He was a member of the vestry of St. Andrew's parish for upward of 38 years and served as its secretary, junior warden and senior warden, which latter position he held at the time of his death. As a member of the diocese convention for fourteen years and a member of the standing committee of the diocese for ten years he rendered efficient service.

All who knew him hold with the vestrymen of his parish that "He was a loyal friend, and those who had the privilege of intimate acquaintance with him found in him the enduring basis upon which true friendship rests. while these most of all mourn his loss, they chiefly have cause for thanking God for the enrichment which that acquaintance has brought into their lives."

HERBERT J. GOULDING.

Digitized by Google



THE NEW POWER PLANT

Digitized by Google

THE MICHIGAN TECHNIC

VOLUME XXVII NUMBER 1

PUBLISHED BY THE

UNIVERSITY OF MICHIGAN ENGINEERING SOCIETY

THE HINGELESS ELASTIC ARCH

F. A. STEIGER

The problem of the hingeless elastic arch is generally solved by graphical methods, which, though only approximate in their results, are more easily understood and applied than any of the complicated analytical methods heretofore offered. In this paper the writer presents a method of solution, a combination of graphical and analytical methods, which is at the same time simple and accurate.

The solution of the problem involves the satisfying of three fundamental equations:

$$Ms/EI = 0 \quad (1)$$
$$Msy/EI = 0 \quad (2)$$
$$Msx/EI = 0 \quad (3)$$

where:

s = length of any short division of arch ring;

M = bending moment at center of such division; and is assumed as the average moment of the division, so that

ΣMs = total bending moment along arch center line;

x and y are the coordinates of the middle points of the spaces s;

E = modulus of elasticity, which is assumed to be a constant;

I = moment of inertia of each section s.

Equation (1) $Ms/EI = 0$, states that, as the arch is fixed in direction at the ends, all changes in direction caused by loads must have a corresponding change in the opposite direction so that the final result or summation of all the changes is zero. Equation (2) $Msy/EI = 0$, means that, since the arch span can not change, the effect of each bend in the arch, as measured by the horizontal change that would be caused in the span, must be offset by a corresponding bend and change of span in the opposite direction, so that the final horizontal result is zero. Equation (3), $Msx/EI = 0$, means that, since neither end of the arch can change its vertical position as compared with the other end, the summation of the vertical effects of all the bends, when taken over the full length of the arch must equal zero.

These three equations can be much simplified by the removal of constant factors. The quantity I is not a constant if the arch ring varies in thickness,

Digitized by Google

but, by varying the length of the spaces s, the ratio s/I can be given a constant value and so can be left outside the sign of summation in each equation, leaving, since E is also a constant,

$$\Sigma M = 0;\ \Sigma My = 0;\ \text{and}\ \Sigma Mx = 0.$$

Furthermore, the bending moment M at any point in the arch is the product of H (the horizontal thrust) and i, the vertical intercept between the arch center line and the correct moment polygon, which it is our problem to find. That is, $M = Hi$, and, substituting this value of M in the equations, we have

$$\Sigma Hi = 0;\ \Sigma Hyi = 0;\ \Sigma Hxi = 0.$$

or since H is a constant, the problem will be solved when we have satisfied the conditions

$$\Sigma i = 0;\ \Sigma yi = 0;\ \text{and}\ \Sigma xi = 0.$$

The equation $\Sigma i = 0$ can be satisfied for any moment polygon simply by moving the polygon up or down to balance the + and — areas. Σyi is a function of H, its positive value increasing as the value of H decreases. Σxi depends upon the position of the polygon with reference to the arch center line, as indicated by the position of the polygon closing line. We have then to determine the value of H and the position of the polygon closing line.

In the special case of a load symmetrically placed both as to amount and position with regard to the middle point of the span, the closing line of the moment polygon is parallel to the spring line of the arch. Σxi does not then have to be considered, since the centers of gravity of the + and — areas are at the middle of the span, so that, when the polygon is in position to make $\Sigma i = 0$, the moments of these areas balance. We have then only to solve for H to make $\Sigma yi = 0$.

The solution of the general case, that is, when the load is eccentric, can be greatly simplified by reducing the problem to the special case of a symmetrical load. To this end, we superimpose upon the given arch AB an identical arch $A'B'$, so that the end B' falls upon the end A, and the end A' falls upon the end B. Then, adding the eccentric loads, we have an arch with a symmetrical load equal to twice the given eccentric load. The H for this arch will be twice the required H, and the moment polygon will have the same ordinates (from the closing line) as the required polygon. Furthermore, two points of the required polygon will be located, as the points where a vertical line through the center of the span cuts the polygon for doubled load and its closing line will remain fixed. We will have then only to collect the position of the polygon closing line to obtain the required bending moment polygon.

To illustrate this method, let us assume an arch of 80 foot span and ten foot rise of center line. The curve of the arch center line may be of any form, but the writer prefers to make it conform to the curve of the moment polygon corresponding to the given dead load.

Digitized by Google

For convenience we will make use of the following notation as indicated in figure 3:

Fig. 1 shows half of the arch subdivided into five spaces of such length as to make s/I a constant. It is customary to substitute an arch into about

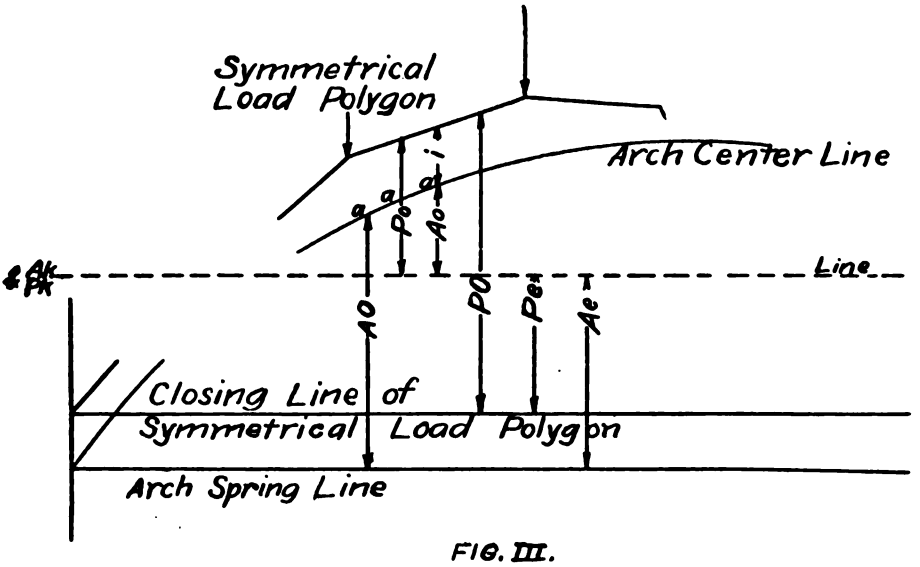


FIG. III.

TABLE I

1	2	3	4	5	6	7	8	9	10
Points	L. & D. Ld.	Points	D. Ld.	Comb. Ld.	Σ Lds.	Arms.	Σ Lds. x Arms	Σ Moments	P. O
11	1880	11	1220	3100	3100	3.30	10230	1,015,252	10.1525
10	000	12	000	000	3100	3.30	10230	1,005,022	10.0502
9	3880	13	2580	6460	9560	3.20	30592	994,792	
8	000	14	000	000	9560	3.70	35372	964,200	9.6420
7	4700	15	3300	8000	17560	3.30	57948	928,828	
6	000	16	000	000	17560	4.40	77264	870,880	8.7088
5	6720	17	5100	11820	29380	3.70	108706	793,616	
4	000	18	000	000	29380	5.30	155714	684,910	6.8491
3	11300	19	9340	20640	50020	4.50	225090	529,196	
2	000	20	000	000	50020	2.80	140056	304,106	3.0411
1	8330	21	7270	15600	65620	2.50	164050	164,050	
	36810		28810	65620			1,015,252		

Assume H = 100,000
Then PO = M/H

twice as many spaces as we have used here, but in this solution the number of spaces is immaterial.

By the construction of a reduced load contour, we can find the dead loads, which we assume to act on lines through their centers of gravity. Let us assume a live load of 200 lbs. a square foot to cover the left half of

Digitized by Google

Load Points Left Half	1	2	3	4	5	6	7	8	9	10	11
Dead Loads	7270		9340		5100		3300		2580		1220
Live Loads	1060		1960		1620		1400		1300		660
Total Loads	8330	000	11300	000	6720	000	4700	000	3880	000	1880

Load Points Right Half	21	20	19	18	17	16	15	14	13	12	11
Dead Loads	7270	000	9340	000	5100	000	3300	000	2580	000	1220

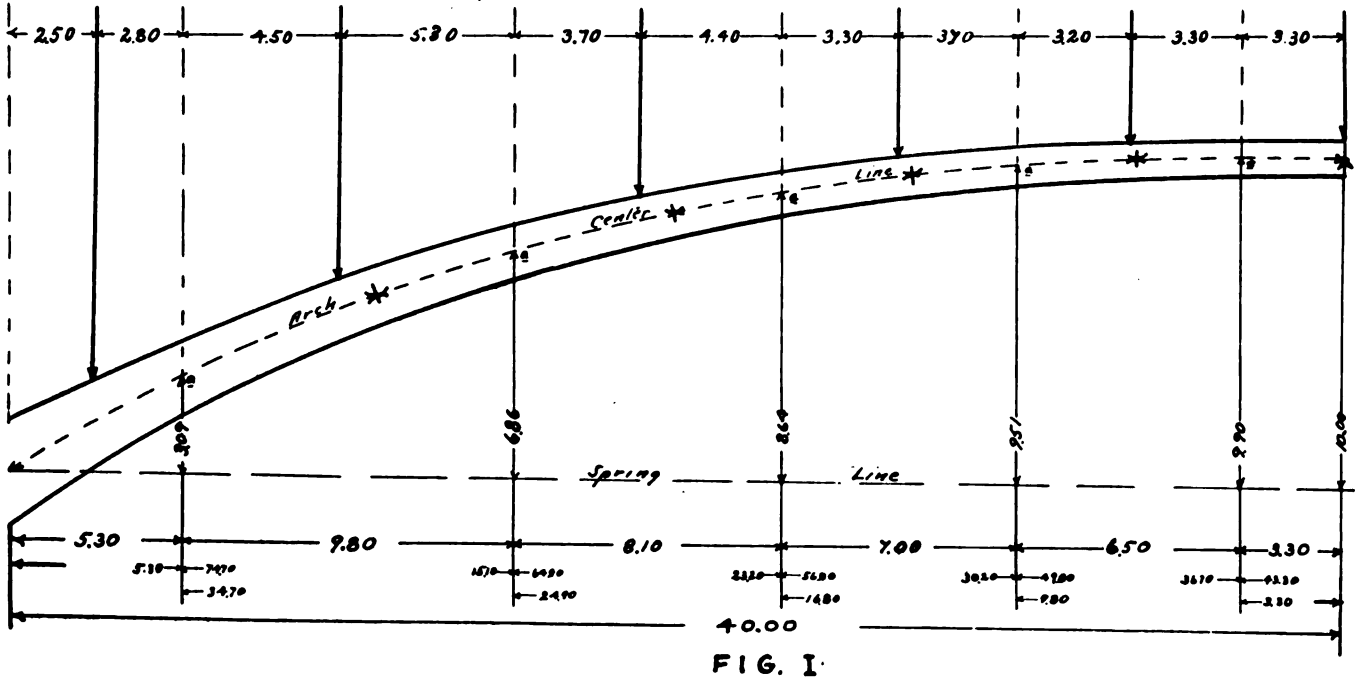


FIG. I

Digitized by Google

the arch. We now have given the form and dimensions of the arch center line, and the amounts and points of application of the loads; we are to find the bending moment polygon which is the result of the given system of loads.

In Table I, Cols. 2 and 4 give the loads on the points as numbered in Cols. 1 and 3, and Col. 5 gives these loads combined. That is, we have reduced our problem to the special case of an arch symmetrically loaded by adding the eccentric loads at corresponding points. This gives us the results in Col. 5, which are the loads on either half of our new, symmetrically loaded arch. Since both halves of this arch are loaded alike, we need consider only one-half the span in calculating the polygon ordinates.

In Col. 6 are set down the part sums of the loads in Col. 5; that is, the first in Col. 6 is equal to the first in Col. 5, the second in Col. 5 being added to make the second in Col. 6, and so on, so that the last in Col. 6 is the sum of the loads in Col. 5.

In Col. 7 are the spacings, toward the abutment, between these loads, and in Col. 8 are the products of Cols. 6 and 7.

In Col. 9 are the summations of the figures in Col. 8, made as in Col. 6, but from the bottom up. It will readily be seen that Col. 9 is a list of the bending moments in one half of a simple beam under this system of loads. From these bending moments we can find the ordinates of a trial polygon, by dividing the moments by any assumed H. Letting the trial H equal 100,000, the trial moment polygon ordinates, at the a points and at the center of the span, will be as given in Col. 10.

In order to make $\Sigma i = 0$, we have but to place the polygon over the arch so that Pk coincides with Ak. Then

$$\Sigma (Po - Ao) = \Sigma i = 0.$$

We have now to consider whether $\Sigma yi = 0$, and if not, we must modify the ordinates and therefore H to satisfy this condition. In the expression Σyi, y is any ordinate to the arch, represented in Fig. 3 by AO. We have then,

$$\Sigma yi = \Sigma AOi = 0.$$

but when Pk and Ak coincide, $i = Po - Ao$.

hence

$$\Sigma (AO.Po - AO.Ao) = 0.$$

or

$$\Sigma (AO.Po) = \Sigma (AO.Ao)$$

but

$$Po = PO - Pe$$

and

$$Ao = AO - Ae$$

$$\Sigma (AO.PO - AO.Pe) = \Sigma (AO^2 - AO.Ae)$$

Since Ae and Pe are constants, we have

$$\Sigma (AO.PO) - Pe \Sigma AO = \Sigma AO^2 - Ae \Sigma AO$$

Digitized by Google

From Table II, $AO = 38$, and for the trial polygon, $PO = 38.2912$. Hence, $Ae = 7.60$ and trial $Pe = 7.6582$. The Table gives all other necessary quantities and we find that

$$\Sigma\, AO.PO - Pe\,\Sigma\, AO = 31.8052$$
$$\Sigma\, AO^2 \quad - Ae\,\Sigma\, AO = 30.9073$$

This shows that the trial polygon ordinates are too large and must be multiplied by $30.9073/31.8092 = .97177$.

Trial h, $10.1525 \times .97177 = 9.8659 =$ true h.
Trial Pe, $7.6582 \times .97177 = 7.442 =$ true Pe.

$Ae - Pe = 7.60 - 7.442 = .158 =$ distance of polygon closing line above arch spring line.

TABLE II

1	2	3	4	5
Points	AO	$(AO)^2$	PO	(AO)x(PO)
10	9.90	98.01	10.0502	99.4970
8	9.51	90.44	9.6420	91.6954
6	8.64	74.6496	8.7088	75.2440
4	6.86	47.0596	6.8491	46.9848
2	3.09	9.5481	3.0411	9.3970
	38.00	319.7073	38.2912	322.8182

$Ae = 38/5 = 7.60$
$Ae \times \Sigma\,(AO) = 7.60 \times 38 = 288.80$
$\Sigma\,(AO)^2 - Ae \times \Sigma\,(AO) = 319.7073 - 288.80 = 30.9073$
$Pe = 38.2912/5 = 7.6582$
$Pe \times \Sigma\,(AO) = 7.6582 \times 38 = 291.0130$
$\Sigma\,(AO \times PO) - Pe\,\Sigma\,(AO) = 322.8182 - 291.0130 = 31.8052$
$30.9073/31.8052 = .97177$
$100000/.97177 = 102905 + =$ True H for doubled load.

True h, $9.8659 + .158 = 10.0239 =$ distance of top of polygon above arch spring line.

$10.0239 - 10.0000 = .0239 =$ true center intercept i.

From Col. 9, Table I, the center bending moment $= 1{,}015{,}252$, which, divided by the true h, 9.8659, $= 102{,}905.2 = H$ for the doubled load. Hence, true $H = 51{,}452.6$.

Having determined the true H, we have now to find the true position of a polygon which is the result of the given eccentric load and the H that we have found, so that $\Sigma\, xi = 0$. Two points of this polygon are already located, *i. e.*, the crown and the point D (Fig. 2), 10.0239 and .158 above the spring line. These points are fixed, for since the arch bending moment and also the simple beam bending moment, at the center of the span, are, for the single load. half that for the doubled load, and since H is also one half, the intercept and ordinate at the center will be the same.

Digitized by Google

Table III is in two similar parts, one part being a calculation to determine the ordinates for the left half of a trial polygon, and the other half the ordinates for the right half. These ordinates, figured as though the halves of the arch were independent, are calculated from the given loads on each half just as was done in Table I for one half the double loaded arch. Instead, however, of dividing the moments in Cols. 6 and 13 by an assumed H to find the ordinates in Cols. 7 and 14, we have divided these moments by the true H as previously found.

TABLE III

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Points	Loads	Σ Lds.	Arms	Σ Lds. x Arms	Σ Moments	PO	Points	Loads	Σ Lds	Arms	Σ Lds. x Arms	Σ Moments	PO
11	1880	1880	3.30	6204	587243	11.4133	11	1220	1220	3.30	4026	428009	8.3185
10	000	1880	3.30	6204	581039	11.2927	12	000	1220	3.30	4026	423983	8.2403
9	3880	5760	3.20	18432	574835		13	2580	3800	3.20	12160	419957	
8	000	5760	3.70	21312	556403	10.8139	14	000	3800	3.70	14060	407797	7.9257
7	4700	10460	3.34	34518	535091		15	3300	7100	3.30	23430	393737	
6	000	10460	4.40	46024	500573	9.7288	16	000	7100	4.40	31240	370307	7.1971
5	6720	17180	3.70	63566	454549		17	5100	12200	3.70	45140	339067	
4	000	17180	5.30	91054	390983	7.5989	18	000	12200	5.30	64660	293927	5.7126
3	11300	28480	4.50	128160	299929		19	9340	21540	4.50	96930	229267	
2	000	28480	2.80	79744	171769	3.3384	20	000	21540	2.80	60312	132337	2.5710
1	8330	36810	2.50	92025	92025		21	7270	28810	2.50	72025	72025	
	36810		4000					28810		4000			

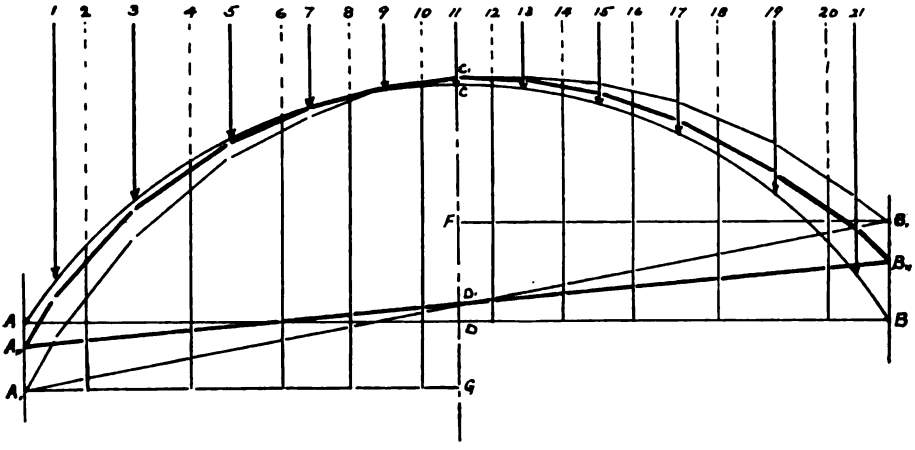


FIG. II

H equals 51452.6 and dividing the moments at point 11 in each half, which is the center point of our arch, by H, we get 11.4133 and 8.3185 as the heights of the loaded and unloaded halves of our polygon, at the center of the span.

These two half polygons formed from the ordinates which might be calculated at the load point from the corresponding moments in Column 6, if drawn starting from the fixed point at the center, .0239 above the crown of the arch, will give a trial moment polygon having the proper H, but which must be tried and corrected in position so as to make $\Sigma xi = 0$.

In figure II the full line represents the arch curve, the light broken line the moment polygon in its trial position, and the heavy broken line the true position of the polygon which we are to find.

Digitized by Google

In the half trial polygon C_1A_1G, C_1 equals 11.4133, being the center height of the loaded half of our moment polygon as given at the top of Col. 7, Table III. Similarly in C_1B_1F. $C_1F = 8.3185$.

The average of these heights C_1G and C_1F is $C_1D_1 = 9.8659$ or the center height of our full polygon above its true closing line A_1B_1. This checks with the center height previously found for our doubled load, and shows that our closing line passes through the point on the center line, .158 above the spring line, as it should.

In order that $\Sigma xi = 0$, the sum of the moments of the ordinates, from the arch spring line to the moment polygon, times the x arms, must equal the sum of the moments of the corresponding arch ordinates times their x arms.

This follows because the intercepts i are equal to the differences between these ordinates.

We will find these moments and compare them and then correct the position of our polygon accordingly.

TABLE IV

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Points	PO	Spring line to Moment Poly. Closure Items	Spring line to Trial Poly	x Arms	(Col 4)x(Col 5)	x Distances	x^2	Triangle Intercepts	Spring line to True Poly	AO	True Intercepts i	yx_2	$x \times i$
(A)	(0.0000)	(-)	(-1.3894)			(40.00)		(+1.1072)	(-.2822)	(0.00)	(-.2822)		
2	3.3384	-1.3894	1.9490	5.30	10.3297			+ .7605	2.9095	309	- .1805	- 5577	- 9567
4	7.5989	"	6.2095	15.10	93.7634			+ .6892	6.8987	686	+ .0387	+ .2653	+ 5844
6	9.7288	"	8.3394	23.20	193.4741			+ .4650	8.8044	864	+ .1644	+1.4204	+3.8141
8	10.8139	"	9.4245	30.20	284.6199			+ .2713	9.6958	951	+ .1858	+1.7670	+5.6112
10	11.2927	"	9.9033	36.70	363.4511			+ .0913	9.9946	990	+ .0946	+ .9365	+3.4718
12	8.2403	+1.7054	9.9457	43.30	430.6488	3.30	10.89	- .0913	9.8544	990	- .0456	- .4514	-1.9745
14	7.9257	"	9.6311	49.80	479.6288	9.80	96.04	- .2713	9.3598	951	- .1502	-1.4284	-7.4800
16	7.1971	"	8.9025	56.80	505.6620	16.80	282.24	- .4650	8.4375	864	- .2025	-1.7496	-11.5020
18	5.7126	"	7.4180	64.90	481.4282	24.90	620.01	- .6892	6.7288	686	- .1312	- .9000	- 8.5149
20	2.5720	"	4.2774	74.70	319.5218	34.70	1204.09	- .9605	3.3169	309	+ .2269	+ .7011	+16.9458
(B)	(0.0000)	(-)	(+1.7054)			(40.00)		(-1.1072)	(.5982)	(0.00)	(.5982)		
					3162.5278		2213.17				-.4158	+5.0328	+30.4307
											-.4158	-5.0328	-30.4307

In Table IV we have set down the ordinates at the a points, as found in Cols. 7 and 14, Table III, but have placed them in their regular order from the left abutment.

In Col. 3 we have — 1.3894 and + 1.7054, being $A A_1$ and $B B_1$, Fig. II, found by subtracting the half polygon heights C_1G and C_1F from C_1D the height of the center of the polygon at C_1 above the spring line. These quantities being subtracted from and added to their respective half polygon ordinates give, in Col. 4, the ordinates from the arch spring line $A B$ to the trial polygon.

In Col. 5 are the x distances from the left abutment to the ordinates and in Col. 6 the products of Col. 4 times Col. 5.

The sum of Col. 6 is the total polygon moment = 3162.5278.

The relative arch moment is equal to the sum of the arch ordinates times the half span, *i. e.*, the sum of the mom. of the corresponding arch ordinates (see fig. 1), is, $2 \times 38 \times 40 = 3040$.

The difference between these moments 122.5278 is the unbalanced moment which we are to correct.

Our polygon moment is larger than our arch moment so the polygon must be changed in position to reduce the ordinates (to the spring line)

Digitized by Google

which correspond to the longest arms, and since the polygon is fixed at the crown and the closing line is fixed at point D_1 the closing line A_1B_1 must swing on point D_1 to the position $A_{11}B_{11}$.

As the lengths of the ordinates from the polygon closing line A_1B_1 to the polygon do not alter (being determined by H and not by the position of the closing line) then the amounts which the ordinates are raised or lowered with reference to the spring line are equal to the intercepts of these ordinates in the triangles $A_1D_1A_{11}$ and $B_1D_1B_{11}$.

From our unbalanced moment 122.5278 we are to find the change in the position of the polygon as indicated by the intercepts of the ordinates in these triangles.

We will not take space to follow the mathematics but it can be shown that these intercepts are equal to

$$Mz/2\Sigma z^2 \qquad (2)$$

where M is the unbalanced moment, and z the distances in either triangle from the center of the span D to the intercepts.

In Col. 7, Table IV, we have these z distances and in Col. 8 their squares. In Col. 9 we have the triangle intercepts figured by the above formula (being the same for both right and left triangles), and in Col. 10 the true polygon ordinates from the spring line $A\,B$ obtained by adding or subtracting, as the case may be, the intercepts in Col. 9 to or from the trial ordinates in Col. 4.

For convenience we have placed the arch ordinates in Col. 11 and by subtracting these from the ordinates in Col. 10 we get the desired intercepts i in Col. 12.

In Col. 13 we have the $y\,i$ moments, and in Col. 14 the $x\,i$ moments.

The footings of these columns show how closely these summations equal zero. It is only a matter of decimal places to make them balance exactly, and therefore satisfy the conditions of our problem.

This method contains no intricate formulas, and the work is all simple arithmetic.

A little study and comparison will show that almost every step has its exact check.

By the use of the present day calculating machines, or, if one is only aiming at practical results, the slide rule, the work is very quickly done and much time should be saved over the graphical method or the more intricate analytical methods.

The example given has been worked out to four places of decimals in order to show what exact results may be obtained, but for practical purposes this is unnecessary. However, it is suggested that in finding the ratio factor that determines the true h from the assumed h the work be carried out several places as the problem is very delicate at thi point. That is, H should be found almost to the last pound if close results are desired.

In Tables I and III the a points are included in their regular order the same as though they were loaded points, and the loads are given as 000. This is because we wish to find the ordinates and intercepts at these points. Some writers figure the bending moments at the loaded points in which case only the loads would be tabled. To shorten our tables we might omit the

Digitized by Google

a points and as our polygons are straight from load point to load point we could find the load point ordinates, and then proportion in the *a* point ordinates. It will be noticed that except for the center ordinates we deal only with the *a* point ordinates.

RESUME

To determine the bending moments in an arch of any dimensions we would proceed as follows:

To the given live and dead load on one-half of the arch add the dead loads (and live loads) at the corresponding points (including the *a* points) on the other half.

This gives us the combined loads as in Col. 5 of Table I. Following out the summations and multiplications as in Cols. 6 to 9 we get the bending moments as in Col. 9.

Assume any horizontal thrust H that will give the trial polygon ordinates by simply moving the decimal points in the moments. Or move the decimal points and multiply or divide by 2 or 3 if necessary, and if it is desired to make the ordinates about equal to the corresponding arch ordinates.

Having the trial ordinates at the *a* points we form Table II and get the factors to apply in equation (1) and thereby get the correction-factor by means of which we find the true H and the true height of the moment polygon corresponding to our combined load.

We also apply this correction factor to the trial *Pe* and then by assuming *Pk* to be placed over *Ak* we get the position of our true polygon for this combined load and are able to locate the hinge points in the polygon and its closing line on the vertical through the center point of the arch.

So far we have solved to make $\Sigma y i = 0$ when $\Sigma i = 0$ and have determined the true H for our given load which is equal to one-half the H which we found for our assumed doubled load.

The eccentric position of our given live and dead loads as regards the center point of our arch span determines $\Sigma x i$ so we now tabulate these loads, beginning at the center point and passing to the abutments either way as shown in Table III.

Carrying out this table as described for Table I we get the bending moments as in Cols. 6 and 13 and dividing these by our true H (one-half that for our combined load) we get in Cols. 7 and 14 a set of polygon ordinates corresponding to either half of our arch but independent of each other.

These are ordinates down to horizontal closing lines parallel to the spring line and by subtracting the center point ordinate in each case from the height of the fixed center hinge point (as previously found) above the spring line we get the distance from the spring line of the arch to the half polygon closing lines in either case. These distances, subtracted or added as the case may be, to the half polygon ordinates at the *a* points give the distances or ordinates from the arch spring line to the *a* points.

The sum of the moments of these ordinates about either abutment when compared with the sum of the moments of the corresponding arch ordinates gives the unbalanced moment of our trial polygon and, by applying formula

Digitized by Google

(2), we get the change in each ordinate necessary to make these moments balance.

Applying these corrections or changes to the ordinates from the spring line to the *a* points, we get the ordinates or distances from the arch spring line to the true polygon in its proper position.

The difference between these ordinates and the corresponding arch ordinates gives the desired intercepts *i* which, when multiplied by our true *H*, gives the desired arch bending moments.

H = Horizontal Thrust in any Moment Polygon.
h = Center height of any Moment Polygon.
Spring Line = Horizontal line connecting ends of Arch center line.
AO = Arch Ordinates from Spring line to *a* points.
PO = Polygon Ordinates from Closing line at *a* points.
Ak = Horizontal line through Arch at heght of average AO
Pk = Horizontal line through Symmetrical-load Polygon at height of average PO.
Ao = Arch Ordinates from Ak line at *a* points.
Po = Polygon Ordinates from Pk line at *a* points.
Ae = Average Arch Ordinate—Spring line to Ak line.
Pe = Average Polygon Ordinate—Closing line to Pk line.
a Points = Points on Arch Center Line at which it is desired to determine the true intercepts *i*.
i = Intercepts between Arch Center Line and Moment Polygon.
x = Horizontal distances from left abutment to ordinates through *a* points.
z = Horizontal distances from center of span to ordinates through *a* points.
y = any arch ordinate.

Digitized by Google

PRACTICAL APPLICATIONS OF LOGARITHMIC PAPER

W. F. VERNER, M.E.

Logarithmic paper has been used for some time by engineers in obtaining equations representing the results of tests where several variables have a bearing on the result. It is also used to obtain graphically certain values in representative equations when other values in the equation are known or assured.

The purpose of this paper is to explain in detail, how to use logarithmic paper, and the method adopted in making charts to be used in connection with the flow of steam in pipes.

The divisions of a logarithmic chart are laid off according to a logarithmic scale and correspond to the spacing on an ordinary slide rule. The paper may be secured from dealers in mathematical instruments. It is of especial service in solving equations by the aid of straight lines, which if plotted upon common co-ordinate paper would mean a set of curves.

Let the simple equation PV — (RT) be considered first. This may be written, log P + log V — log (RT), which is the equation of a straight line.

Part 1 of Chart 1 shows a portion of the plain logarithmic paper. It is desired to obtain the value of one of the variables in the above equation when the other two are known. The ordinates of Part 2 at the left are used to represent values of "P" ranging from 1 to 10, and the abscissae at the bottom to represent values of "V" covering the same range. If 45 degree diagonals are drawn from the left and down to the right they will represent constant values of (RT) from 1 to 100. It is then possible by means of the diagonals to obtain graphically the value of "P", "V" or (RT) when the other two are known.

Example:

Let "P" = 5 and "V" — 6 to obtain (RT). Pass horizontally along the line representing the value of "P — 5 until it intersects the vertical line representing the value of "V" — 6. The diagonal passing thru this intersection gives the product, or 30.

It is apparent that if (RT) and "P" are known the value of "V" could be obtained. And if (RT) and "V" are known "P" could be obtained.

Diagonals of 45 degrees might also be drawn from the left and up to the right which as shown on Part 3 will represent the quotient of the co-ordinates "P" and "V".

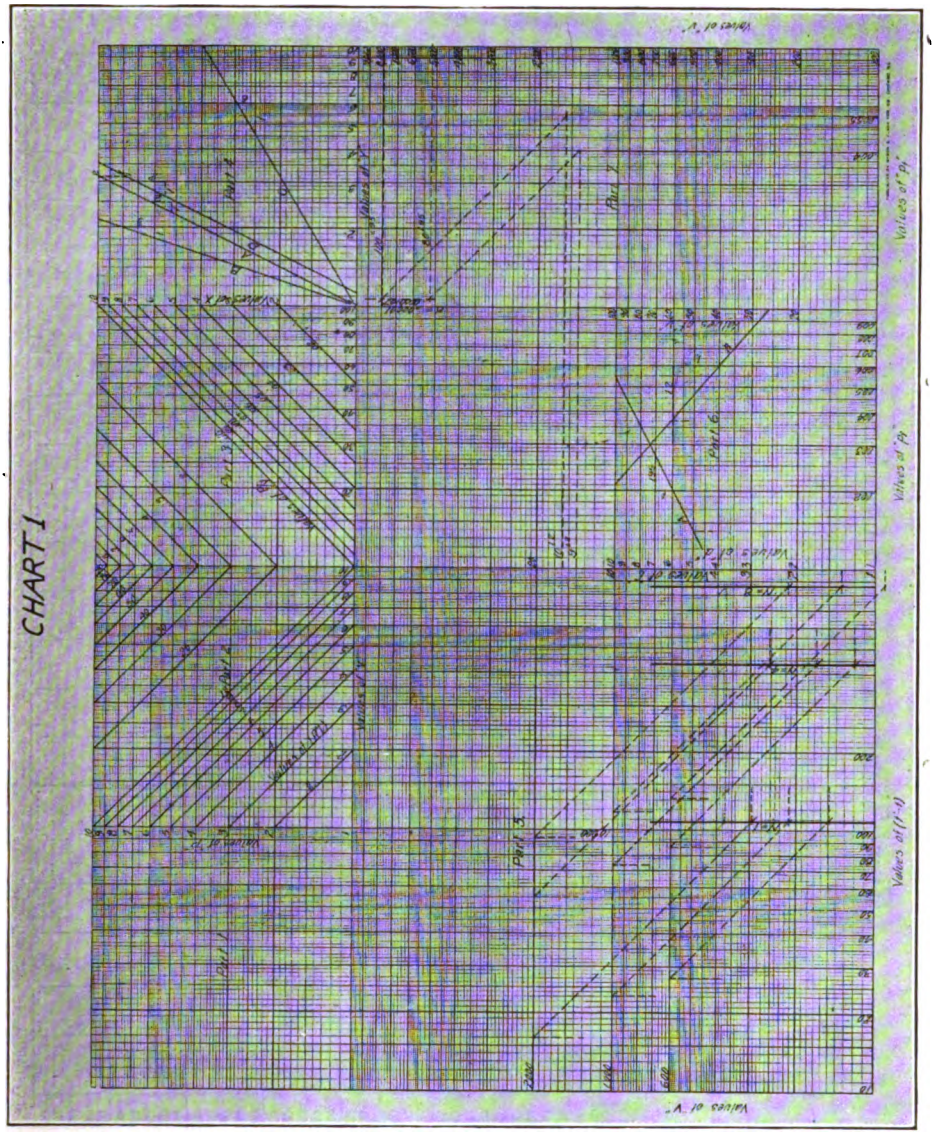
Part 4 illustrates equations containing two variables on of which is raised to a certain power.

Line A is for $x = y^2$ which may be written $\log x = 2 \log y$. The slope of the line is an indication of the power or 2 to 1.

Line B is for $x = y^3$. Slope 3 to 1.

Line C is for $x = y^{.6}$ Slope .6 to 1.

Digitized by Google



Line D is for $x = .7854y^2$. which is the equation for the area "x" of a circle of diameter y. The constant causes a shifting of the square line downward as y^2 is reduced in being equated to x by a distance of "ef" equal to (1—.7854) on the logarithmic scale.

Part 5 represents a chart for determining an equation containing the variables of Table 1. which is a table from the American Radiator Company's Bulletin on Vento Cast Iron Heaters.

Digitized by Google

Final Temperatures and Condensations

NARROW SECTION—Standard spacing, 5" Centers of Loops—Steam 227°, 5 lbs. Gauge. Air entering above zero.

Number of Stacks Deep	Temperature of Entering Air	Final Temp Air Leaving Heater	Cond Lbs. Per Sq. Ft. Per Hour	Velocity Through Heater in Feet per Minute—Measured at 70°																							
				100		200		400		600		800		1000		1200		1400		1600		1800		2000			
				FT	C.	FT	C	FT	C	F.T.	C	F.T.	C	FT	C	FT	C.	FT	C.	FT.	C.	FT	C	F.T.	C.		
1	90	70	43	66	53	74	60	74	60	47	43	43	1 84	45	2 18	41	2 36	39	2 45	37	2 55	36	2 65	35	2 75	34	2 86
	80	77	42	73	50	68	67	68	64	1 49	1 39	43	1 70	51	1 85	49	2 10	48	2 19	47	2 30	46	2 39	45	2 49	44	2 59
	70	84	41	80	46	64	73	64	60	1 33	1 28	42	1 66	58	1 84	58	1 99	57	2 10	56	2 19	55	2 30	54	2 39	53	2 49
	60	90	39	86	40	60	80	60	55	1 47	1 17	41	1 47	66	1 66	67	1 77	66	1 84	65	1 91	64	2 00	63	2 08	62	2 18
	50	103	38	105	37	56	86	56	50	1 11	1 06	39	1 33	74	1 47	85	1 56	84	1 61	83	1 68	82	1 75	81	1 82	80	1 88
2	90	108	99	101	45	70	56	64	61	1 56	1 46	66	1 83	66	2 02	59	2 16	58	2 26	54	2 36	54	2 45	53	2 55	52	2 65
	80	110	57	108	44	66	61	61	58	1 39	1 30	63	1 67	69	1 77	68	1 90	64	1 99	64	2 08	63	2 16	62	2 24	61	2 33
	70	116	53	114	40	62	66	58	56	1 24	1 16	60	1 49	72	1 58	74	1 70	72	1 77	72	1 84	71	1 91	70	1 98	69	2 06
	60	120	50	120	34	58	70	54	52	1 10	1 03	57	1 33	75	1 41	80	1 51	80	1 57	80	1 63	79	1 70	78	1 76	77	1 83
	50	131	48	126	31	54	73	50	48	1 00	94	54	1 20	78	1 28	86	1 36	86	1 42	86	1 48	86	1 54	85	1 60	84	1 66
3	90	131	99	113	38	80	64	74	58	1 39	1 30	64	1 67	79	1 81	73	2 05	71	2 19	71	2 30	69	2 40	68	2 49	67	2 59
	80	138	57	130	55	78	67	72	64	1 33	1 24	62	1 60	83	1 73	81	1 88	78	2 06	78	2 16	77	2 25	76	2 34	75	2 43
	70	140	51	138	53	76	70	70	68	1 28	1 19	60	1 53	86	1 66	88	1 77	85	1 94	84	2 03	84	2 11	83	2 20	82	2 28
	60					74	73	68	72	1 23	1 14	58	1 47	89	1 58	95	1 66	92	1 82	91	1 90	91	1 98	90	2 06	89	2 14
	50					72	76	66	76	1 18	1 09	56	1 40	92	1 50	102	1 57	99	1 70	98	1 77	98	1 84	97	1 91	96	1 98
4	90					90	113	80	84	1 39	1 30	84	1 67	79	1 81	73	2 05	71	2 19	71	2 30	69	2 40	68	2 49	67	2 59
	80					88	120	78	82	1 33	1 24	82	1 60	83	1 73	81	1 88	78	2 06	78	2 16	77	2 25	76	2 34	75	2 43
	70					86	125	76	80	1 28	1 19	80	1 53	86	1 66	88	1 77	85	1 94	84	2 03	84	2 11	83	2 20	82	2 28
	60					84	128	74	78	1 23	1 14	78	1 47	89	1 58	95	1 66	92	1 82	91	1 90	91	1 98	90	2 06	89	2 14
	50					82	131	72	76	1 18	1 09	76	1 40	92	1 50	102	1 57	99	1 70	98	1 77	98	1 84	97	1 91	96	1 98
5	90					110	118	94	84	1 39	1 30	94	1 67	98	1 81	106	1 98	106	2 08	106	2 19	105	2 30	104	2 40	103	2 49
	80					108	126	92	88	1 33	1 24	92	1 60	102	1 73	111	1 88	111	1 99	111	2 09	110	2 19	109	2 28	108	2 37
	70					106	133	90	92	1 28	1 19	90	1 53	106	1 66	117	1 77	117	1 91	116	2 00	116	2 08	115	2 17	114	2 25
	60					104	138	88	96	1 23	1 14	88	1 47	111	1 58	123	1 66	123	1 82	122	1 90	122	1 98	121	2 06	120	2 14
	50					102	141	86	98	1 18	1 09	86	1 40	115	1 50	128	1 57	128	1 70	127	1 77	127	1 84	126	1 91	125	1 98
6	90					120	133	106	92	1 39	1 30	102	1 67	118	1 81	118	1 98	117	2 08	117	2 19	116	2 30	115	2 40	114	2 49
	80					118	138	104	96	1 33	1 24	100	1 60	123	1 73	129	1 88	128	1 99	128	2 09	127	2 19	126	2 28	125	2 37
	70					116	143	102	100	1 28	1 19	98	1 53	127	1 66	139	1 77	139	1 91	138	2 00	138	2 08	137	2 17	136	2 25
	60					114	148	100	104	1 23	1 14	96	1 47	131	1 58	145	1 66	145	1 82	144	1 90	144	1 98	143	2 06	142	2 14
	50					112	151	98	106	1 18	1 09	94	1 40	135	1 50	150	1 57	150	1 70	149	1 77	149	1 84	148	1 91	147	1 98
7	90					130	143	116	100	1 39	1 30	110	1 67	138	1 81	138	1 98	137	2 08	137	2 19	136	2 30	135	2 40	134	2 49
	80					128	148	114	104	1 33	1 24	108	1 60	143	1 73	149	1 88	148	1 99	148	2 09	147	2 19	146	2 28	145	2 37
	70					126	153	112	108	1 28	1 19	106	1 53	147	1 66	159	1 77	159	1 91	158	2 00	158	2 08	157	2 17	156	2 25
	60					124	158	110	112	1 23	1 14	104	1 47	151	1 58	165	1 66	165	1 82	164	1 90	164	1 98	163	2 06	162	2 14
	50					122	161	108	114	1 18	1 09	102	1 40	155	1 50	170	1 57	170	1 70	169	1 77	169	1 84	168	1 91	167	1 98
8	90					140	153	126	108	1 39	1 30	120	1 67	158	1 81	158	1 98	157	2 08	157	2 19	156	2 30	155	2 40	154	2 49
	80					138	158	124	112	1 33	1 24	118	1 60	163	1 73	169	1 88	168	1 99	168	2 09	167	2 19	166	2 28	165	2 37
	70					136	163	122	116	1 28	1 19	116	1 53	167	1 66	179	1 77	179	1 91	178	2 00	178	2 08	177	2 17	176	2 25
	60					134	168	120	122	1 23	1 14	114	1 47	171	1 58	185	1 66	185	1 82	184	1 90	184	1 98	183	2 06	182	2 14
	50					132	171	118	124	1 18	1 09	112	1 40	175	1 50	190	1 57	190	1 70	189	1 77	189	1 84	188	1 91	187	1 98

It will be noted that the condensation per sq. ft. per hour decreases as the number of stacks is increased when the velocity is constant. Also the condensation per sq. ft. per hour increases as the velocity increases for a finite number of stacks. The greater the temperature range the greater the condensation will be, other conditions being constant.

Digitized by Google

Therefore, we may write

$$C \text{ is some function of } v\,(t'-t)/N. \qquad (1)$$

or,

$$C \text{ times some function of } N = \text{some function of } v\,(t'-t). \qquad (2)$$

It appears from the equation that the condensation per sq. ft. per hour, "C", times some function of the number of stacks "N" is equal to the product of some function of the velocity of the air in feet per second "v" and some function of the difference between the final and initial temperatures $(t^1 - t)$.

Let us then assume "v" as an ordinate at the left of Part 5, Chart I: $(t^1 - t)$ as an abscissa at the bottom; "C" as an ordinate at the right to locate the "N" lines.

Take values from the tables such as given in Table 2.

TABLE 2.

v	t'	t	$(t'-t)$	C	N
600	47	20	27	1.49	1
1,000	43	20	23	2.12	1
2,000	36	20	16	2.95	1
600	106	20	86	1.19	4
1,000	93	20	73	1.68	4
2,000	75	20	55	2.53	4
600	152	20	132	.91	8
1,000	137	20	117	1.35	8
2,000	113	20	93	2.14	8

Referring to Part 2 it will be noted that the 45 degree diagonals represent the product of "P" and "IV". On Part 5 a 45 degree diagonal drawn from the left and down to the right will represent the product of "v" and some function of $(t^1 - t)$ which will also be the product of some function of "N" and some function of "C" (see equation 2).

Since the 45 degree diagonal represents the product of any functions of "C" and "N" intersecting upon it and function "C" is represented by horizontal lines then the "N" function lines must be vertical.

Locate the intersection of "v" and a corresponding value of $(t^1 - t)$ as of Table 2 and draw 45 degree diagonals as indicated on the chart until they intersect corresponding values of "C".

It will be noted that the "N" lines are vertical and spaced as the single power. That is the distance between $N = 1$ and $N = 4$ is equal to the distance between 1 and 4 on the abscissa scale. Therefore none of the variables have an exponent.

Take the intersection of $v = 100$ and $(t^1 - t) = 100$. The product equals 10,000. The value of "C" intersecting at this point is 1. Therefore if no constant entered into the equation the "N" line thru this point would be 10,000. It is evident then that some constant greater than 10,000 must

Digitized by Google

be applied to "N". The "N" line of value 1 crosses the 100 velocity line at slightly less than 11,000. Knowing that the equation contains only an unknown constant its value may be obtained by solution, or 10,870.

$$10870\ NC = v\,(t' - t). \tag{3}$$

Table 3 gives value obtained from "Mechanics of Heating and Ventilating" by Meiers' for flow of steam in standard weight iron pipes at 70 lb. per sq. in. mean pressure.

TABLE 3.

Pressure drop per ft. of pipe in lbs. per sq. in. (P_t).	.0014	.0035	.0055	.0027	.0037	.006	.004	.004	.004
Velocity in ft. per sec. (v).	50	80	100	60	60	60	80	69	56
Diameter of pipe in inches (d).	10	10	10	8	6	4	9	7	5

From the table it will be noted that the pressure drop increases as the velocity increases when the diameter is constant, and decreases as the diameter increases when the velocity is constant. It is evident then that the equation must be of the form

$$P_t = \frac{K \text{ times some function of } V}{\text{some function of } d.} \tag{4}$$

K = a constant.

By plotting the values of "P_t" with "V", keeping the diameter constant, a line will be secured whose slope will indicate a power.

Line A of Part 6 shows that "V" has the exponent 1.95.

Line B indicates that when "V" is constant "P_t" varies inversely as the 1.2ths power of "d".

The equation may now be written

$$P_t = \frac{K V^{1.95}}{d^{1.2}} \tag{5}$$

The equation could be solved for "K", knowing corresponding values of "P_t", "d" and "V".

Part 7 illustrates the method of securing the constant K. The line representing the diameters raised to the 1.2 power are obtained by laying off a distance from 1 equal 1.2 times the lineal distance between 1 and the pipe diameter line. Locating the velocity lines and proceeding in a manner as followed for Part 5 the constant is found to be equal to .0000107 and the complete equation is

$$P_t = \frac{.0000107\ V^{1.95}}{d^{1.2}} \tag{6}$$

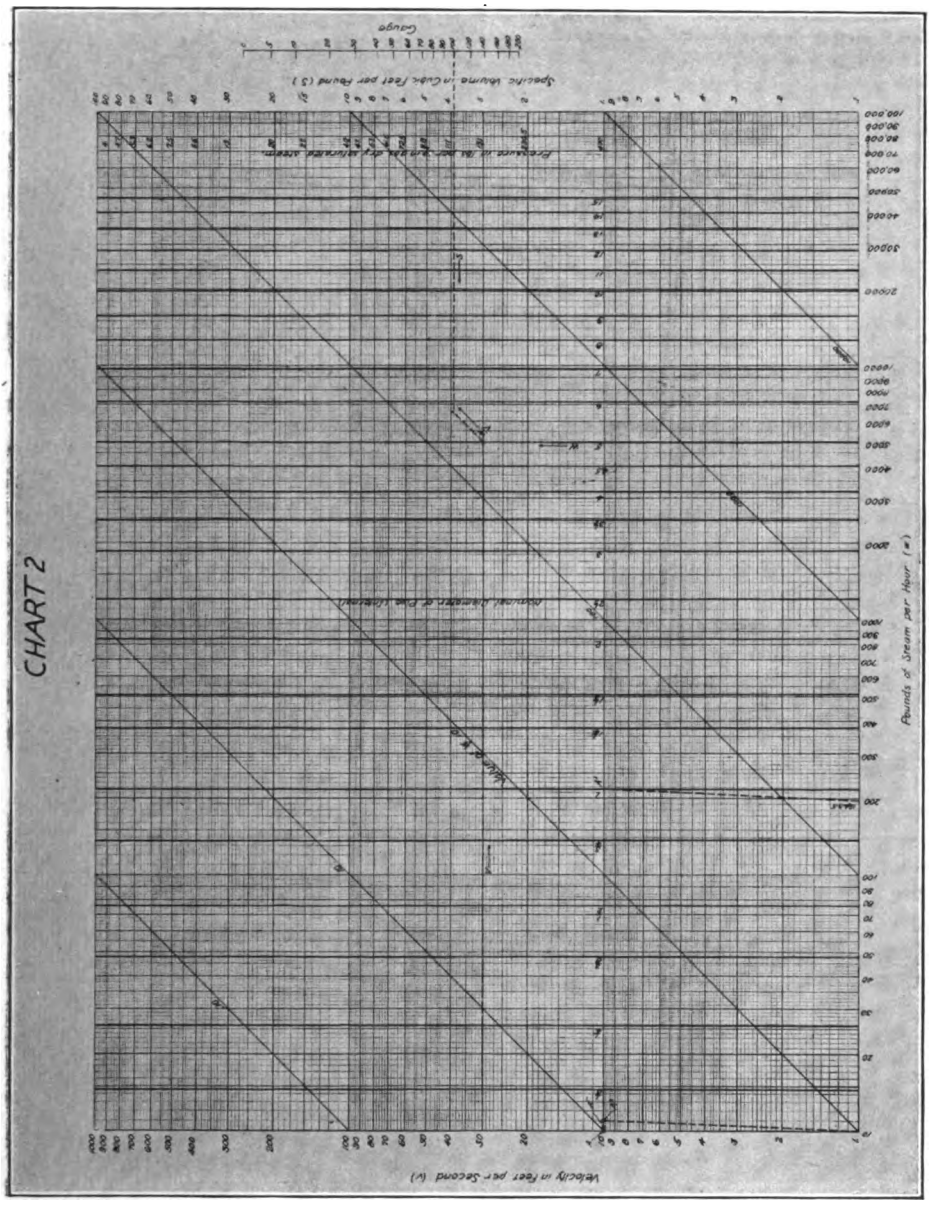
The pressure drop for 'l' feet of pipe would be

$$P_t = \frac{.0000107\ V^{1.95} l}{d^{1.2}} \tag{7}$$

remembering that it applies only for a mean pressure in the line of 70 lbs. per sq. in.

The equation with four variables will now be considered. In determining the proper size of a steam pipe to handle "w" pounds of steam per hour

Digitized by Google



Digitized by Google

Digitized by Google

at not to exceed a certain average velocity "v" in feet per second it is necessary to know the pressure and quality of the steam in order to obtain the specific volume. The actual inside diameter of the pipe may be obtained from the equation:

$$\frac{\pi d^2}{4r \times 144} = \frac{ws}{3600\, v} \qquad (8)$$

Where

d = actual inside diameter in inches.

w = lbs. of steam per hour.

s = specific volume or cu. ft. per lb.

v = velocity of steam in feet per second.

Chart 2 represents a chart which enables the graphical solution of the above equation. The value of any variable may be obtained when the other three are known.

To construct the chart the following method was used:

The ordinates at the left were designated as values of the velocity in feet per second extending from 1 ft. per second to 1,000 ft. per second.

The abscissae at the base were used as pounds of steam per hour from 10 lbs. to 100,000 lbs.

The ordinates at the right were designated as values of the specific volume from .1 cu. ft. to 100 cu. ft. per lb. of steam. A supplementary scale giving the pressure corresponding to the specific valume for dry saturated steam was added.

The next step was to determine the positions of the vertical lines representing the diameters of standard wroght iron pipe.

Referring to Part 3, Chart 1, it will be noted that if a 45 degree diagonal be drawn from the right and down to the left it will represent the quotient of the values of "P" and "V" intersecting upon it.

The equation $\pi d^2/4 \times 144 = ws/3600\, v$ may be put in the form which will show that the quotient of two of the variables with their constant will equal the quotient of the other two.

$$W/S = 3600\pi d^2/4 \times 144s = 19.635d^2/S$$

Therefore on the chart the diagonal representing W/V must be the diagonal representing $19.635d^2/S$.

Since "S" is represented by horizontal lines then values of "d" must be represented by vertical lines increasing from the left to the right. It is then an easy matter to locate the lines corresponding to the standard pipe sizes.

Take for instance the case of a 6 inch pipe whose actual inside diameter is 6.055 inches. Assume "w" = 1,000 and "v" = 10. Solve the equation for "S."

$$S = 19.635d^2v/W = 7.22.$$

Through the intersection of the horizontal line representing "v" = 10 and the vertical line "w" = 1,000 draw the 45 degree diagonal representing the quotient $w/v = 100$ until it intersects the horizontal line representing $S = 7.22$. A vertical line drawn through this last intersection will represent the 6 inch pipe.

Digitized by Google

The other pipe lines are located in a similar manner.

Example—

A 200 H. P. engine requires 5,000 lbs. of steam (dry saturated) per hour at 100 lbs. gage. What diameter pipe is necessary, allowing an average velocity of 1,800 ft. per minute or 30 ft. per second?

Locate the intersection of the vertical line representing 5,000 lbs. of steam per hour and the horizontal line of 30 feet per second. Through this intersection draw a 45 degree diagonal from the right down to the left and note where it intersects the line representing 100 lbs. gage. The intersection indicates that it will be necessary to use a 6 inch pipe.

Referring again to Chart 2 and the method as described above for constructing the chart it will be observed that the equation was solved for "s" in determining the position of the lines representing the pipe diameter. This may be done in another manner similar to the method used in slide rule operation. Suppose the equation were of the form $w/v = d/s$ then the 1 inch actual inside diameter pipe line would be represented by the left hand vertical edge of the chart. That is the 1 inch pipe pine would intersect the specific volume of 1 cu. ft. on the 45 degree diagonal representing the value of 1.0 for w/v or at A. However, as the actual inside diameter of a 1 inch pipe is 1.049 inches it will be necessary to move A to the right to 1.049 or at A'. In the equation the expression $19.635d^2$ occurs. If we square the diameter it will be necessary to double the distance from A or as we do in logarithms multiply the log of 1.049 by 2 to find the log o f$(1.049)^2$. This will bring the point to A^2 or 1.1004. As "d^2" is multiplied by 19.635 it will then be necessary to add the distance 19.635 which would locate the 1 inch pipe line as indicated on the chart at A^2.

An equation arrived at by the author for determining the diameter of a steam pipe in low pressure heating work between o and 3 lbs. gage using constants as obtained from Luftungs und Heizungs Anlagen" by Reitschel is used to construct the chart 3.

The equation for straight unobstructed pipe is

$$d = .0048 \sqrt{\frac{l\,(h + h')\,h}{P}}$$

where

d = actual inside diameter of pipe in inches.
l = length of pipe line in feet.
h = B.T.U. (latent heat) required at discharge end of pipe per hr.
h = B.T.U. lost in pipe line per hour.
p = the drop in pressure in lbs. per sq. in. or the difference between the final and initial pressure.

At the left are values of P.
At the bottom are values of $(h + h')$.
At the right are values of h.
At the top are values of l.

These coordinates were so chosen as to give 45 degree diagonals intersecting at right angles. The equation it will be noted contains the expressions $h\,(h + h')$, which is represented by a 45 degree diagonal drawn from

Digitized by Google

the left and down to the right, and l/P, which is represented by a 45 degree diagonal at right angles to the $h\ (h + h')$ diagonal. As these two expressions are multiplied in the equation, the diameter lines will be vertical and spaced according to the fifth power of "d" divided by the fifth power of .0048.

To locate the diameter lines values of l, h and $(h + h')$ were assumed of such values as to make the solution of the equation simple. Take for instance, the location of the 3 inch pipe line.

Let $h = 1{,}000{,}000$, $(h + h') = 1{,}000{,}000$ and $l = 1{,}000$.

Then

$$d = .0048 \sqrt{\frac{1{,}000\ (1{,}000{,}000)^2}{P}}$$

$$\text{or } d/4.8 = l/P \text{ and } P = (4.8/3.068)^5 = 9.3$$

Draw the 45 degree diagonal representing $h\ (h + h')$ or 10^{12}. Through the intersection of the vertical line representing $l = 1{,}000$ and the horizontal line representing $P = 9.3$ draw the 45 degree diagonal representing l/P. The 3 inch diameter pipe line will pass vertically through the intersection of the two diagonals.

Example—

Consider a pipe line 600 feet long which is to deliver 550,000 B.T.U. per hour to a heating system. Initial pressure 3 lbs. gage. Final pressure 2 lbs. gage. Assume 30,000 B.T.U. lost in transit per hour.

$$h = 550{,}000$$
$$(h + h') = 580{,}000$$
$$l = 600$$
$$P = 1$$

Draw a 45 degree diagonal as indicated on the chart through the intersection of the "h" line, of 550,000 and the $(h + h')$ line of 580,000. Draw a 45 degree diagonal as indicated through the intersection of the "l" line of 600 and the "P" line of 1 lb. The intersection of the diagonals show a pipe size slightly less than 3½ inches. It will then be necessary to use a 3½ inch pipe and the pressure drop will be less than 1 lb. To obtain this drop in pressure draw a 45 degree diagonal l/P through the intersection of the $h\ (h + h')$ diagonal and the 3½ inch pipe line until it intersects the 600 ft. "l" line and read the pressure drop on the horizontal or .88.

The above results may be obtained by the use of the slide rule but considerable care is necessary in keeping track of the decimal point.

Much of the work done by an engineer, especially one who is an expert in certain lines, is often the repeated application of certain formulas. Any mechanical means for solving the equations which involve substitutions of different variables means a saving of time and mental wear and tear.

Many excellent charts have appeared within the last few years but very little information has been printed as to the method used in making charts.

If further information is desired relative to "Graphical Charts" the reader is referred to Maurice d'Ocagne in his excellent text on the subject "Traité de Monographie," and John B. Peddle, "The Construction of Graphical Charts," published by McGraw Hill Book Company.

Digitized by Google

THE USE OF GROINS FOR SHORE PROTECTION

R. R. TINKHAM, '05 E

That a sea-wall itself should require protection from the seas may seem to be a strange circumstance; however, such was the experience of the writer when, on an exposed part of the Lake Huron shore, it became necessary to devise and speedily construct a scheme of shore protection for the preservation of a sea-wall partly undermined and in imminent danger of destruction by action of the seas.

A system of groining was adopted and constructed with immediate and satisfactory results.

The sea-wall is a familiar form of shore protection needing no comment other than to point out its chief characteristics, viz.; that it is a cliff-like structure placed along a shore front, replacing the yielding shore with a hard material to resist the attack of seas; and, because of the power of seas, it is necessarily a massive and expensive structure.

Groins are different in every way. They constructed intersecting the shore line; they do not depend upon their mass and hardness to resist sea action, but utilize natural marine forces as defense against the power of those forces; they are comparatively light structures and, therefore, less expensive.

To explain the use and application of groins, however, it is necessary first to outline the forces acting on the forces acting on the shores. The ultimate result of these forces is erosion, and by shore protection is meant protection against erosion of the shore.

PHYSICAL ASPECTS

On large bodies of water, such as the seas and the Great Lakes, there is no static equilibrium of materials composing the shore. There is continuous erosion and continuous accretion with consequent movement of materials. Sometimes conditions are such that accretion balances erosion and there is no apparent change in the shore. More often, however, one predominates and there results either a cutting away and a receding shore-line, or a building up and an increasing shore line. The latter condition is rare when compared with the former, and results only when certain physical characteristics are present, such as headlands and inflowing rivers situated where littoral draft is pronounced.

A notable example of accumulations around a headland is Tawas Point, Lake Huron. This point has extended three thousand feet in length during the last forty years, and accretion is continuous.

The effect of a river flowing into the lake is to interrupt the alongshore drift with resulting deposit above and opposite the mouth. Erosion continues below compensating accretion and as this accumulation

Digitized by Google

above and erosion below continues, the mouth of the stream is forced in the direction of drift, sometimes for miles until a firm shore material is encountered. The Big Two Hearted River on Lake Superior, and Snake River on Lake Michigan illustrate this action.

EROSIVE AND TRANSLATORY FORCES

The principal forces acting on shores may be designated as,

A. Elements.
B. Waves.
C. Currents.

A. Elements.

The elementary agents of erosion are wind, frost, rain and land springs. The action of these forces is generally well known and little need be said concerning them. The inland observer, however, cannot have experienced the maximum fore of wind attained over the uninterrupted space of the lakes. Illustrating this force, the writer has observed on Grand Island, Lake Superior, sand and large gravel stones carried from the beach over a cliff 175 feet high, and the glass plates protecting the lenticular apparatus of the Grand Island Light, which is 205 feet above lake level, are chipped and scratched by this wind driven gravel. Dunes are formed by dry beach sand carried inland by the wind.

Frost action in disintegrating rock is well known. Interesting evidence of this action is observed on Isle Royale, Lake Superior, the only place in the world where the chlorastrolite or "green stone" appears. These curious stones occur in the igneous black trap rock of Isle Royale, much as garnets occur in granite, and are much sought by tourists. The illuminating fact is that these stones are comparatively plentiful on certain beaches in the spring, but can rarely be found after the tourist season in the fall. A curious effect of frost is apparent in league with seas and grinding ice on Michigan Island, Apostle Group, Lake Superior. The shores of this island are precipitous bluffs of hard pan from 35 to 65 feet high, and on the exposed east banks erosion is proceeding rapidly. Frost hardens these bluffs to the consistency of soft sand rock, which wear away at the base under the atcion of grinding ice to almost perpendicular cliffs. When frost leaves in the spring these "cliffs" slide into the lake, carrying the banks and vegetation above. Aided by rain and surface water, these slides continue through the summer until the angle of repose is reached. Figure I is from a photograph taken on this shore in midsummer. The erosive action of rain is quite apparent.

B. Waves.

The wave is the principal agent of erosion and its action is important in considering methods for protection.

The surface of the free wave, unaffected by outside influence, e. g., a dead sea in deep water, has the form of the familiar sine curve. There

Digitized by Google

is no forward movement of water, but each particle has a movement of circular oscillation forward on the crest and backward in the trough of equal velocity and duration. This oscillation is greatest at the surface, and decreases in amplitude in geometrical progression as the depth of water increases in arithmetical progression until motion ceases. The longer the wave length the deeper this oscillation extends. Short high waves are comparatively shallow.

MICHIGAN ISLAND, LAKE SUPERIOR

SPLIT ROCK, LAKE SUPERIOR

A wave driven by the wind loses its regular surface form, the oscillation of particles are not complete and a forward movement of water results, which in the case of a continued blow forms currents in the direction of the wind, known as wind currents.

When the wave reaches shoal water, its length and velocity decrease and its height increases; the resultant oscillation become elliptical, tilted upward and flatter toward the bottom with increasing amplitude, reaching a mere linear oscillation on the bottom and parallel thereto. Figure 3 illustrates these formations.

The trough of the wave always precedes the crest, i. e., the lower return sweep comes before the upper forward movement. Note the out-

Digitized by Google

rush of water preceding the first crest of the wake when a ship passes near shore, sometimes uncovering the shore two or three feet. The wave rushing toward shore, breaks when the water becomes so shallow that there is not sufficient water to supply this backward upsweep of the face of the wave. The distance from shore that a wave breaks, therefore varies directly as the size and depth of the wave.

When a wave breaks, the mass of water constituting the back or crest of the wave, plunges forward and, impelled by the velocity of the wave, rushes up the beach until the force of gravity offsets the velocity by the law of $V^2 = 2gh$, and the mass of water comes to rest; then returns down the sloping shore with increasing velocity in accordance with the same law. Wind driven waves follow so closely as a rule that the return rush of a proceeding wave meets the plunges of that following, often breaking it up with the resulting deposit of material carried by it. Usually, however, the plunge rises over the back rush, or undertow, with no appreciable interruption to either.

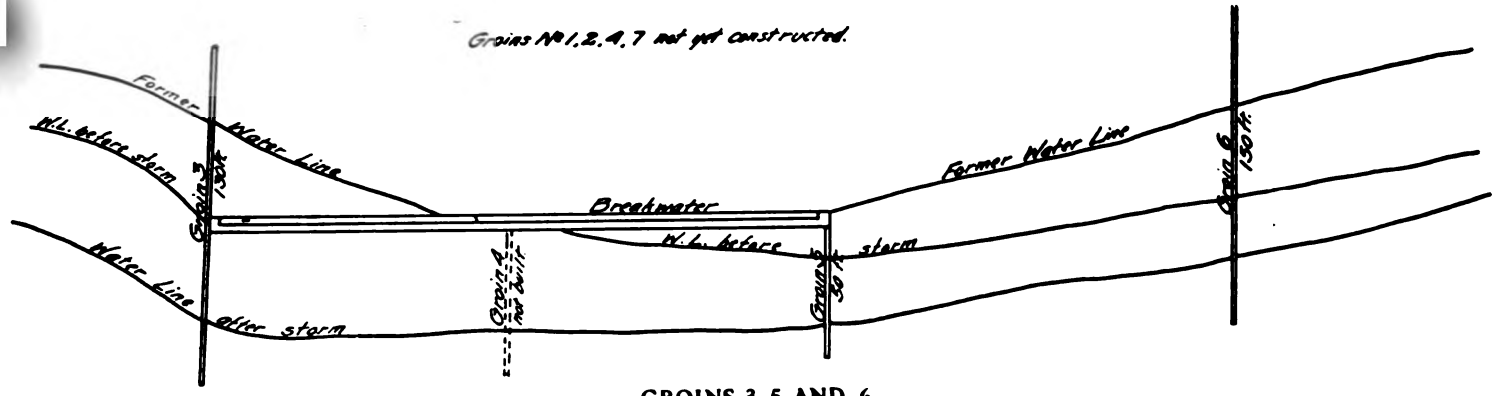
The erosive action is as follows:--The plunge of the wave strikes the bottom violently, stirring up the sand and silt into suspension and driving gravel and stones before it along the bottom. At the point of zero velocity all heavy materials are deposited, but as the undertow gains velocity the finer material held in suspension is swept seaward, the materials being deposited in order of their size and weight as gravity overcomes the viscosity of the water. Silt being held in suspension indefinitely, eventually finds its way into deep water and is deposited at undisturbed depths. The transport of material is greater as the shore is approached, because of the greater amplitude of oscillation.

While the forward and backward swings of oscillation are probably equal seaward of the plunge, yet the backward swing down the slope has the advantage of the aid of gravity, producing a gradual seaward movement of the material on the bottom, which does not cease until the depth of no wave disturbance is reached. The gradient of the foreshore is determined by gravity, tending to approach an angle of repose such that the force of the undertow aided by gravity shall equal the force of the upward plunge aided by the wave velocity. This produces long gradual slopes on sand beaches and short, steep slopes on gravel or boulder shores.

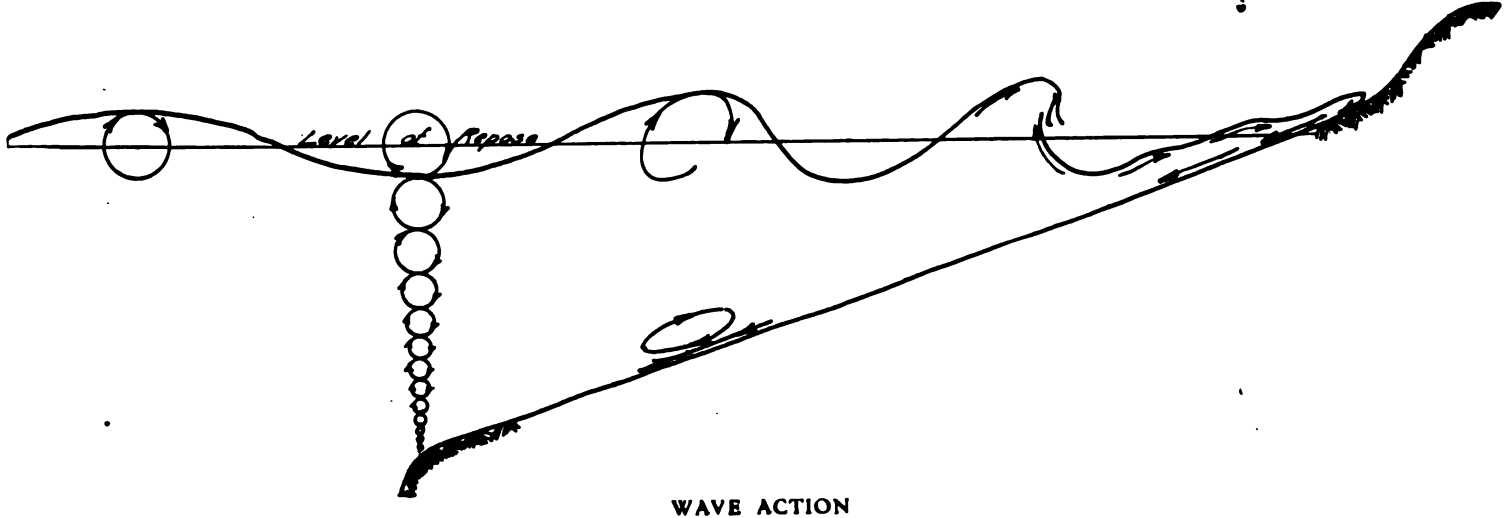
The fact that on all large bodies of water there exists a submerged plateau whose edge or bank skirts the shore at a varying distance and at a depth of water corresponding to the maximum depth of wave disturbance, is a striking illustration of this erosive action, the conclusion being that where oscillation ceases no further translation of material occurs.

All waves, irrespective of direction other than offshore, tend to break parallel to the shore line, due in the case of oblique waves, to the retarding action of shoal water at the inner end of the wave. The angle of incidence, therefore, depends on the gradient of the shore.

Digitized by Google



GROINS 3, 5 AND 6

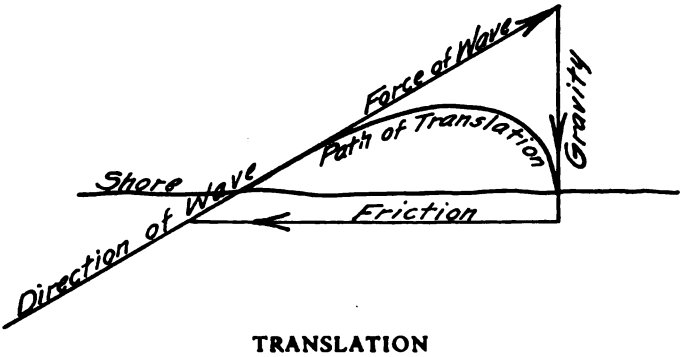


WAVE ACTION

Digitized by Google

Only oblique waves, i. e., waves striking the shore at an angle, cause translation or alongshore movement of materials. This occurs in the manner indicated in the sketch, Figure 4, where the translation is governed by the retarding action of gravity upshore and friction alongshore This movement is often very great, particularly on boulder or gravel shores where the gradient is usually steep.

The power in the impact of waves is enormous. Various measurements of this force are on record, the usual maximum being about 3,000 lbs. per sq. ft., though some measurements are recorded as high as 7,000 lbs. per sq. ft. The greatest impact is produced midway between trough and crest. The writer has seen mass concrete blocks forming the toe of a breakwater, measuring each 8 ft. long, 6 ft. wide and 4 ft. thick. turned completely over by seas. Sixty twenty-five foot sections of the Harbor Beach breakwater, Lake Huron, constructed of mass concrete on stone filled cribs, were broken up and some of them destroyed by wave impact in the storm of November 9, 1913. Wave pressure on porous rock and



TRANSLATION

crevices filled with water, exerts bursting effect becoming explosive when the crevices are filled with air. Rock fragments broken from cliffs in this manner and by frost are hurled about by the waves and produce rapid erosion of cliffs, as well as attrition of foreshore materials. Figure 5 is from a photograph taken at Devils Island, Apostle Group, Lake Superior, illustrating the action of waves on hard sand rock without the aid of rock fragments or foreshore material of any kind; and Figure 2, from a photograph at Split Rock, Minn., Lake Superior, illustrates the combined action of frost and attrition.

C. Currents.

As waves are chiefly responsible for erosion, so are currents the principal agents of translation of materials.

Currents are of various kinds, according to origin. There has been given above the cause of wind currents, generally the most important on the Great Lakes as regard movement of shore materials. In fact sand movement is due almost entirely to the combined action of oblique waves

Digitized by Google

and wind currents, except in certain limited localities where natural stream currents predominate. Wave translation alone is not great, as is apparent when a shift of wind drives waves in a direction opposed to the wind current then flowing, it being observed that the drift is with the current.

As a rule these currents parallel the shore line; however, with a direct onshore wind blowing, a surface current is set up and a piling up of the water follows, which results in a compensating offshore current or undertow with consequent erosion and rapid seaward travel of materials stirred up by the waves. Conversly an offshore wind often produces an onshore undercurrent with resulting accretion, although this is rarely as strong as the erosive action.

DEVILS ISLAND, LAKE SUPERIOR

Natural Stream currents on the Great Lakes, produced by the flow of the lakes toward the sea, are very strong in certain localities and are important to navigation because of the narrowing of the channels. They affect very materially the shores in these places, especially in conjunction with prevailing winds.

Other currents are induced by variation in barometric pressure. A rise of one inch in the barometer will produce a water depression of from six to twelve inches. The writen has witnessed a rise in water level on the south shore of Lake Superior of thirty inches in six hours. This is unusual, although variations in level of one foot are common and they seem to occur at very irregular intervals, due no doubt, to variations in the barometer and not to tidal action. This is borne out by the custom of lake mariners to regard such changes as indications of a blow in the direction of high water.

Digitized by Google

On the sea coasts tidal currents are the most important forces for movement of shore materials in conjunction with wave action very similar to the action of wind currents on the lakes.

On the transporting power of currents lies their importance and this seems to follow well defined principles.

These may be briefly stated as follows:

The surface velocity of a current is about 1.5 times the bottom velocity. Sediment in suspension reduces the velocity of a current. The diameters of suspended particles vary directly as the square of the velocity of the current and their weights vary directly as the sixth power of its velocity.

Presence of suspended materials in a current increases its density. The pressure exerted by a current tending to move particles varies directly as the density of the fluid. The velocity of a current necessary to move materials at rest varies inversely as the square root of the fluid density. The current velocity necessary to move materials, e. g. gravel, in mass is four times that required to move single pieces.

An undisturbed, perfect current has the properties of still water, so far as suspension or transport of material is concerned. Such currents do not occur along shores, but the fact emphasizes the importance, such as produced by eddies in the suspension and translation of materials, and the equal importance of breaking up such disturbance to produce accumulation.

It has been found that currents from one to three feet per second cause movement of particles on the bottom in the form of short sand wave ripples of very low velocity. Higher current velocity produces stream motion of material along the bottom and still higher velocity of current produces surface waves which apparently cause the formation of long sand waves on the bottom, varying from three to twenty feet in length. This wave length increase with the increase in depth and velocity of the current. These high velocities produce movement of stones on the bottom, but the amount of stone and coarse gravel moved by alongshore currents is negligible because of low current velocity.

Suspension is necessary for appreciable movement of materials by currents and this depends upon the viscosity of the water, upward thrust of eddies and upon the fact that suspended particles follow lines of least resistance and, therefore, move upward into currents of higher velocity. Also a greater quantity of fine material than coarse of the same density is carried in suspension, because the surface areas of the smaller particles are greater in proportion to their weights.

Rate of settlement is also important in the deposition of shore materials. In currents, time of settlement varies as the square root of the diameters of the larger particles, and as the square of the diameters of the smaller. Settlement of fine silt is affected by the temperature, occurring twice as fast in summer as in winter.

Digitized by Google

CONCLUSIONS

Summing up, the movement of gravel and boulders is produced by waves alone, and translation of this material is caused by oblique wave action, all movement taking place by rolling along the bottom. Sand and silt, driven into suspension by wave action, are chiefly transported by alongshore currents and deposited in accordance with the size of the particles or carried seaward by undertow wave action and deposited according to the same principle. Sand, due to its inertia, is easily thrown out of twisting currents and eddies and deposited, while silt remains in suspension, following the slightest current and is eventually carried into deep water before settlement occurs, beyond the influence of currents. The size of particles of bottom materials decreases as the depth of water increases.

It has been determined by various experiments and observations that the quantity of alongshore drift decreases as the distance from shore increases, which is a fact of importance to be considered in protection work.

GROINS

Purpose.

Groins have been briefly defined in a preceding paragraph. It will now be apparent that the purpose of groin construction is to intercept the movement of shore materials and in that way check the erosion of the shore; and, where conditions are favorable, to cause an extension of the shore line by causing deposition of drift, thus forming an efficient protection against encroachment of the seas and, what is more important, a protection that constantly increases in efficiency.

It is not always possible to cause accretion, but if properly applied it is always possible to check erosion by taking advantage of the simple material principles above outlined.

Direction.

There has been much difference of opinion regarding the proper direction for groins, some advocating groins in the direction of prevailing winds, others oblique groins extending away from prevailing winds, and still others favoring a construction normal to the shore line. The latter has become general practice, principally because oblique groins tend to set up seaward or onshore currents that become detrimental and even a serious menace to the accomplishment of the original purpose, by reason of scour and seaward movement of materials.

These discussions refer to foreign practice, where groins are used much more extensively than in this country. In fact, groining on the Great Lakes is very limited, there being but three such constructions within the knowledge of the writer.

Length.

Length is another indefinite matter. On the sea coast it is customary now to build groins extending from above H. W. M. to a short distance beyond L. W. M., except on gravel and boulder coasts,

Digitized by Google

where much shorter groins are sufficient because of the behavior and translation of gravel in accordance with the principles above outlined.

Two things may be considered to determine the length of lake groins, whether the drift is composed of gravel and boulders only, and the probable distance from shore that drift occurs in any quantity, roughly determinate by the gradient of the foreshore. The groin should extend somewhat beyond the limit of drift, because of the tendency to scour around the end of the groin, and in all cases should extend inshore well into the bank above H. W. M. to prevent seas cutting behind it.

Spacing.

This is a matter that must be determined from experience and for each locality separately, depending upon conditions. Too great a distance between groins may cause erosion, and if too close together a continuous agitation of the water will prevent accumulation. Roughly, lake groins should be spaced a distance equal to the length of groin seaward of the water line.

Height.

This is another much debated question in foreign practice, but best results seem to have been obtained with low groins, i. e., those not over three feet above the shore level, which permit of material passing over the top during high tides, thus equalizing deposition either side of the groin. Experience with high groins has been that great quantities of material collect on the windward side and erosion takes place to leeward, all of which is unsightly, dangerous to pedestrians, and jeopardizes the groin itself, if not even a protected sea-wall, by undermining. On the tideless waters of the Great Lakes other considerations enter into the question and the height will vary depending on the method of construction, exposure, etc. This will be mentioned again below.

Types.

The use of groins dates from the seventeenth century, but only in recent years has the practice been very extensive. Types of construction are almost as numerous as the groins themselves.

In England they are constructed of masonry, sometimes as massive as sea-walls, of mass concrete, of wood piles with intermediate sheet piling, sometimes covered with galvanized iron, of continuous wood piling, and of reinforced concrete posts with intermediate reinforced concrete curtain walls built up in sections. The latter type, called the Case groin, is now usually constructed. It is a low groin and the movable curtain wall sections permit of extending the height as accumulation increases.

In Holland groins are almost always constructed of wood and straw facines covered with earth and capped with gravel and stone.

At Blankenberghe are wide, flat groins with curved top and sloping sides about thirty feet wide, constructed of facines and concrete, capped with brick and stone.

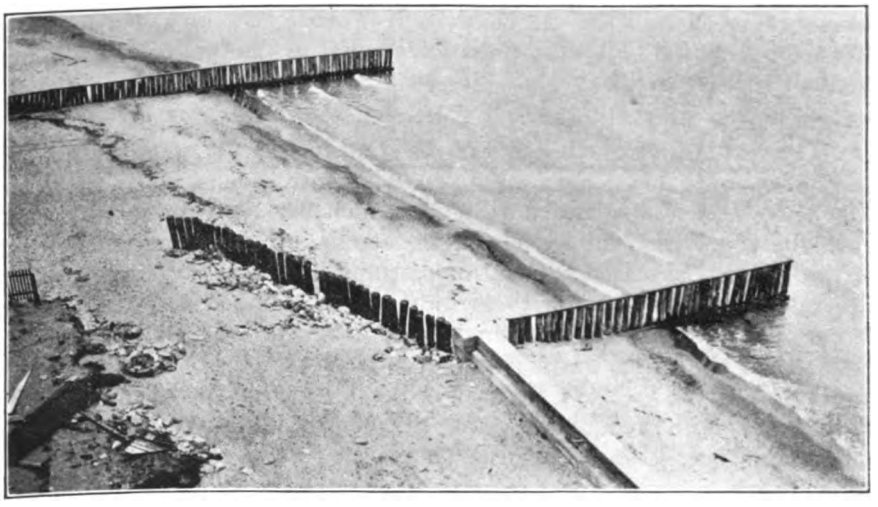
Digitized by Google

At Mecklenburg are groins of two rows of piles between which are packed facines secured by cross timbers. Here a beach has formed 6½ feet deep and 164 feet wide in nine years.

In Italy groins are built, at enormous expense, of masonry and rock more on the manner of breakwater and jetty construction in this country.

Lake Groins.

The first groins on the Greak Lakes, to his knowledge, were located by the writer in 1908 at Whitefish Point, Lake Superior, and were constructed during the three following seasons. These are of rough log cribs,drift pinned and filled with one man stone, varying in length from twenty feet to one hundred feet, eight feet wide and averaging three



GROINS 5 AND 6

feet above water level. Erosion, which was very rapid before their construction, has been stopped. Accretion of sand is variable, usually extending the length of the groins on the prevailing windward sides, sometimes covering them completely, and at other times after a severe storm from the opposite quarter the groins are left clear of sand as originally constructed. There is no gravel on this side of the point.

In 1911, similar groins were constructed at Sand Point, Lake Superior, with the result that the cribs became buried in sand, extending the shore line to the ends of the groins.

Last year the case mentioned in the opening paragraphs arose and it fell to the writer to devise and construct protection. The conditions there were unusual in that a natural current of about four miles per hour set past this shore, which had a steep gradient and was exposed to the full sweep of Lake Huron and oblique wave action in the direction of the current.

Digitized by Google

A system of groining was laid out as shown in Figure 7, but it was decided to construct only groins 3, 5, and 6 at that time, as an immediate protection to the sea wall, and to watch the action of these groins before proceeding with further construction.

Groins were first designed using Lackawanna Interlocking Steel Sheet Pilling painted with an inhibitive paint and driven to a depth sufficient to resist maximum ice pressure, being 10 feet with the fulcrum 2 feet below the surface of the sand. This construction was abandoned because of the comparatively high cost in consideration of the experimental nature of the project. There is, too, some doubt as to the efficiency of a tight groin here, owing to the danger of setting up serious scour by deflecting this high current around the ends of the groins.

The groins then devised and later constructed were for the reason last stated above, made of continuous wood piling, piles 10 inches to 16 inches in diameter, driven as close together as they could be handled, leaving the spaces between for the passage of the current. They were driven deep enough to resist ice pressure, and extended 6 feet above water to act as wave breakers. A cap timber was put on to hold the alignment until permanent double wales could be bolted up.

Results were immediate. Before the completion of the groins the shore built out as shown in Figure 7, being 25 feet at groin No. 6. Two days after the completion of the last groin a terrific storm swept the lakes with an unusual rise of water at this point and had it not been for the groins so recently completed, which acted as wave breakers, the sea-wall and several valuable structures fronting it would have been annihilated. As it happened, the seas broke around the shore end of No. 6 and washed out quantities of sand. Groin No. 6 was later extended 65 feet inshore. During this one storm the beach made out in front of the sea-wall 35 feet as indicated in Figure 7. Figure 6 is from a photograph taken after the storm showing groin No. 5 at the end of the breakwater and groin No. 6 beyond. The former beach line followed the dark drift line shown nearly in line with the old pile fence.

Digitized by Google

ENGINEERING ASPECTS OF THE GYROSCOPE WITH SPECIAL REFERENCE TO STABILIZING PROBLEMS

JOHN AIREY, D.I.C.

The name gyroscope was given by Foucault, a French physicist, to that which most of us recognize by that name and are familiar with chiefly in the form of a toy.

A gyroscope or gyrostat in its broader engineering sense is a rapidly rotating heavy wheel, whose axis of rotation is itself changing in direction. There appears to be no definite distinction in the use of the terms gyroscope and gyrostat; the most rational would appear in calling an action gyroscopic when precession is quite free or controllable at will; and gyrostatic when the axis of rotation is fixed relatively to some large structure. According to this distinction gyrostatic action is usually incidental and not desired—is tolerated because it cannot be got rid of, as may be seen in an auto, train, motorcycle or aëroplane making a curve; gyroscopic action on the contrary is the most salient feature of the mechanism; as in monorail mechanism, Schlick's steadying apparatus, the gyro-compass.

For a long time back gyroscopic phenomena have interested both the initiated and the laity. The powers and knowledge of the former have been frequently taxed to the utmost in the attempt to explain fully some manifestations; the latter have been fascinated by something which appears to be immune from the elementary laws of mechanics.

Until comparatively recently this subject was at home almost exclusively in the domain of mathematics. However, engineers have had the subject brought to the fore in the last decade, first by things which have been accomplished mainly by the use of gyroscopes and which would otherwise be more difficult of solution—monorails, and so forth; second, where gyrostatic effects come in incidentally and cause unlooked for stresses and therefore have to be allowed for in design. In innumerable cases gyrostatic action comes in to a greater or less extent. It is worth remembering that as speeds increase so does the importance of gyrostatic action; hence it follows that cases which, a few decades ago, could be ignored from this point of view, can now no longer be ignored, due to the all-round increases of speeds. In many cases gyrostatic action exists in principle, though of such small magnitude as to be negligible, although this negligibility must be proved and not assumed.

The subject having developed almost exclusively in a mathematical atmosphere, it is not surprising that it brings with it a heritage of complexity into engineering. This is a pity. Most engineers believe that there is some-

* Part of this article and some of the cuts are used through courtesy of the "American Machinist."

Digitized by Google

thing intrinsically difficult in getting a clear idea of the fundamental principle involved and that it would take more time to master it than they care to give. This state of affairs is not to be wondered at, as the viewpoint of the pure mathematician and the engineering mathematician are essentially different. The former insists on a rigorous solution embodying all conditions no matter how complex. The latter is ready to approximate, if by so doing, he can cut down complexity and so more easily retain his physical grasp of the problem. The mathematician builds up the most general case and deduces easy cases from this as particular examples; the engineer begins with the simplest case and gradually builds up the more difficult ones. It is true that if one wishes to pursue all the ramifications of gyroscopic phenomena to the limit quantitatively, then the most advanced mathematical machinery may be used to advantage. The important thing to the engineer is, however, first to understand the phenomena qualitatively, and second, to be able to handle the simplest case (with constant precessional velocity) quantitatively. The further than this that one goes, the better, but this is amply sufficient (and needs no more than very elementary mechanics) to prevent engineers being scared off gyroscopic phenomena as something intensely mathematical.

The gyroscope has already done remarkable things and the future will probably see other equally or more remarkable applications in practice. There is no reason why a man of no mathematical knowledge but of inventive genius could not advantageously study the gyroscope. The magnitude of the action can be sensed sufficiently for a preliminary trial; and with all the mathematics possible recourse must always be had finally to experiment. I do not underrate the advantage of mathematical ability in studying the gyroscope, but wish to make it clear that lack of that knowledge does not deter a man from applying it to new problems.

In 1874 a great amount of money was spent in trying to keep the saloon of a ship steady in spite of a heavy roll of the boat. The attempt was made by Sir Henry Bessemer, of steel fame, a gyrostat being employed. According to the distinction given between gyroscope and gyrostat, the fiasco can be tersely explained by saying that they employed a gyrostat whereas they should have employed a gyroscope. If the men in charge of that venture had understood gyroscopic action simply from a qualitative point of view that blunder and consequent waste of money would never have occurred.

Probably most readers are already vaguely acquainted with gyroscopic action. If not, then take a portable electric fan, hold it in the hands when running with the axis horizontal and then give a sharp twist about a vertical axis; or take a toy gyroscope, spin it and put it in its box with the lid on; now twist the box spasmodically in any direction. There will be a decided kick felt—rather suggestive of the thing being alive. The reason why the gyroscope is sometimes facetiously attributed with occult powers is because if you try to twist it about a given line, it will not move at all, or very little, about that line, but will move about some other axis, probably at right angles with the first axis. All this erratic behavior can be boiled down to one simple rule.

Digitized by Google

Discussion of Principle.

The most convenient way to take up the study of the gyroscope is to get a small model, as shown in Fig. 1. This can be obtained for 25c.

If the model be placed as shown in Figs. 1 and 2, one end on the tripod and with its axis horizontal, then if not spinning it will immediately fall down, but if spinning fairly fast it will scarcely fall at all, but revolve bodily around a vertical axis through *A*.

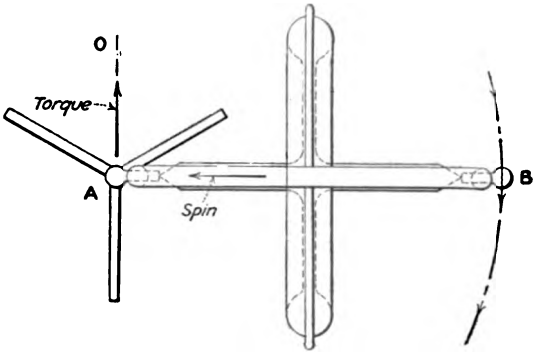
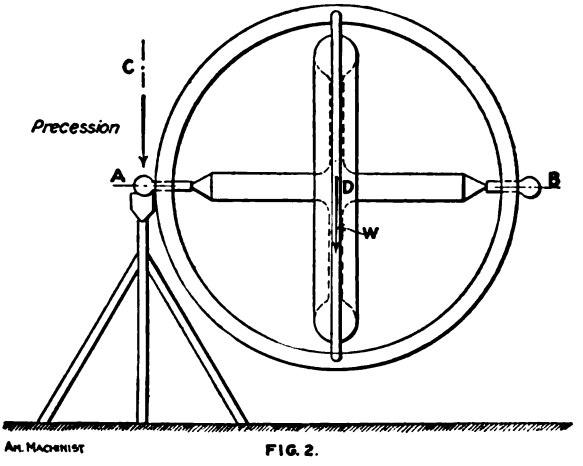


FIG. 1



Am. Machinist FIG. 2.

In any gyroscope there are three important axes, the *spin* axis, the *precession* axis and the *torque* axis.

In examining any gyroscopic mechanism, these axes should be the first things to look for; if two are located, the third can always be found by a simple rule. In the simplest case these axes are mutually perpendicular. Let us determine each of these axes in the present case. The easiest to note is the spin axis, as this is the axle of the wheel *AB*. It will be noticed that the whole framework swings bodily as if it were attached to a vertical spindle through the center of the tripod. The line *AC* is in consequence

Digitized by Google

called the precession axis. The center of gravity of the wheel and frame is at D, and the weight acting through here may be represented by an arrow W. The force W is exerting a moment $W \times AD$ about a line AO (see Fig. 1, which is a plan of Fig. 2). Because the tendency of the unsupported weight is to cause rotation about AO, this line is called the torque axis. If the wheel is rotating clockwise when viewed from B, then the point B will be found to precess clockwise in Fig. 1, and counterclockwise, if the motion of the wheel be reversed.

To reduce this to a simple rule, it is necessary to standardize the way of representing torque and rotation. Rotation of the wheel about AB is represented by an arrow from B to A; the arrowhead must point from B to A. This is easily remembered by the fact that a corkscrew, if turned with the wheel, will travel from B to A. If the wheel's rotation were reversed, the arrowhead would also be reversed. For the same reason the torque axis is AO, not OA. Now for the rule:

The spin axis, if free to move, always takes the shortest course which will enable it to set itself parallel to the torque axis, the arrow heads to point in the same direction.

If the spin axis is not free to move in this way, then it will tend to do so and a sufficiently strong reaction will have to be provided to prevent it so moving. It is evident that for BA to try to set itself along AO, the motion must be clockwise in Fig. 1.

Let the spin be N r.p.m. about AB, and the precession be n r.p.m. about AC, then it will be shown that:

$$W \times AD = 0.01096\, InN$$

W is the weight of the wheel and frame in lb.;
I is the moment of inertia of the wheel in engineers units of mass $\times$ ft^2.

Proof of Fundamental Formula When Precessional Velocity Is Constant.

In any standard textbook on theoretical mechanics it is proved that Torque = Rate of Change of Moment of Momentum; also that Torque and Moment of Momentum are vector quantities.

In Figs. 3 and 4 two views of a disk are shown which is rotating about OZ as axis and is making ω radians per sec. OZ is shown in Fig. 3 and is normal to plane of paper in Fig. 4. A torque of T lb.-ft. about OX is caused to act on it. The Moment of Momentum may be represented by a vector OZ whose length is $I\omega$ (= Mo. of Momtm.) to some convenient scale.

Torque = Rate of Change of Mo. of Mom. is written $T = I\, d\omega/dt$ or $T\,\delta t = I\,\delta\omega$ where δt and $\delta\omega$ are small increments of time and angular velocity respectively.

In time δt a torque T about OX will cause an increase of Mo. of Mom. = $T\,\delta t$ along OX. This is laid off to scale as shown. Now the resultant will be the vector sum of these two, or R in Fig. 3. For this to be true it is evident that the framework must have so turned that the axis is in

Digitized by Google

the line R; that is, the gyro has precessed through an angle $\delta\theta$. Imagine this disk to be the wheel of Figs. 1 and 2. Its precessional velocity is therefore $\delta\theta/\delta t = \Omega$ (say) rads. per sec.

Also $\delta\theta = T\,\delta t/I\,\omega$ therefore

$$\delta\theta/\delta t = \Omega = T/I\omega$$

or

$$T = I\,\omega\,\Omega = 0.01096\,InN.$$

This equation is proved on the supposition that the precessional velocity is constant. No further complication than this is needed for the purpose of

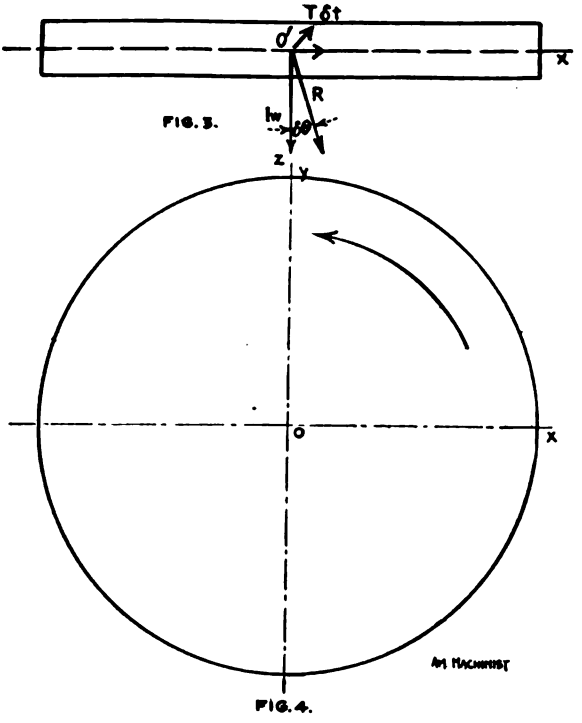


FIG. 3.

FIG. 4.

grasping the fundamental principle of gyroscopic action. Another assumption made is that N is a great many times larger than n. This is abundantly true in all practical applications. The pure mathematician usually does not make use of this assumption and so adds greatly to the difficulty of the solution without reaping any advantage therefrom.

What the Equation Means.

A careful study of this equation will now be taken up, helped by experimental check, the better to sense the facts. In this equation can be seen why the Bessemer Saloon was a failure, why the monorail car does not fall over, how ships can be steadied and why a gyro-compass is possible.

Digitized by Google

Let us put this equation in words:

$$Torque = Spin \times Precession \times a\ Constant.$$

If, therefore, the spin be reduced, the precession will increase and *vice versa*, that is assuming the torque to remain constant. Check by experiment. If the spin keep constant then precession increases with the torque. Try this by hanging a small weight at B. Now artificially increase the precession by holding a pencil vertically and following up B slightly, helping it onward. If precession increases then the above equation states that torque increases also; but the torque to be counteracted is the same as before, W at a leverage AD. The gyroscopic torque is now (due to artificially increased precession) more than sufficient to hold W at a leverage AD from falling, and actually lifts it. The point D will be found to move upward as well as onward. This is the essence of the monorail car.

Next slightly impede the precessional motion by holding a pencil in front of B and pressing gently backward. The equation states that if the precession be decreased, then the torque is also decreased; but there is still $W \times AD$ to be counteracted. What happens? The gyroscopic torque is decreased and must, therefore, be insufficient to hold up the wheel, the result is that the center of gravity slowly falls. It falls slowly because the supporting moment is only slightly and not completely annulled. The fact that the precession has some value other than zero partially counteracts the fall. Carry this to the extreme and hold the pencil so that the precession is stopped dead. Result! *The wheel falls exactly as if it were not spinning.* This is of vast importance. If precession is not permitted then there is no counteracting torque. Lack of appreciation of this fact was the sole cause why, in 1874, the expensive attempt to make a ship's saloon remain steady in a rough sea was a failure and remained unsolved until the beginning of the next century, when Herr Otto Schlick successfully attacked the problem.

It is often said and is widely believed that a spinning wheel tries to keep its axis of rotation always the same. Implicit belief in this has been the cause of many erroneous ideas. This statement is not true except under certain conditions. To come back to Fig. 1. The resultant force W tends to make the gyroscope turn about AO, but does not succeed in doing so, *so long as it is free to precess about AC*. If not (when the pencil was held in front), then it turns about AO, just exactly as if the wheel were not spinning. So that in either case the axis of spin changes and will change no matter how small W may be. The real anomaly lies in the fact that, if free to precess, it does not move in the way one would expect, but it does move nevertheless.

Practical Applications.

Gyroscopes have been applied (and practically all in the last decade) with the following results:

(a) The roll of a ship has been reduced, and can be reduced to any extent desired, even to zero.

Digitized by Google

(b) A ship has been made to roll even though waves are absent. This has been used to enable a ship to shake itself free from ice when opening a track for itself. This can be done much more efficiently if the ship goes forward with a regular roll, as this prevents a wedging action in the ice.

(c) A ship has been made to pitch for the purpose of ice-breaking.

(d) A torpedo has been made to keep a constant direction independent of the waves tending to skew it.

(e) Platforms for quick-firing guns have been kept level in spite of the roll of the ship.

(f) A one-rail train has been made a practical venture; though it remains to be seen whether it is a commercial venture on any large scale.

(g) An aëroplane has been made automatically to keep a level deck.

(h) Last, but probably most important of all, a compass has been made which will determine the true geographical North and so enable navigators to be independent of the variable and troublesome magnetic North; also in the future, it will probably enable one to be independent of fine days or starry nights in accurate survey work.

Application to Ships

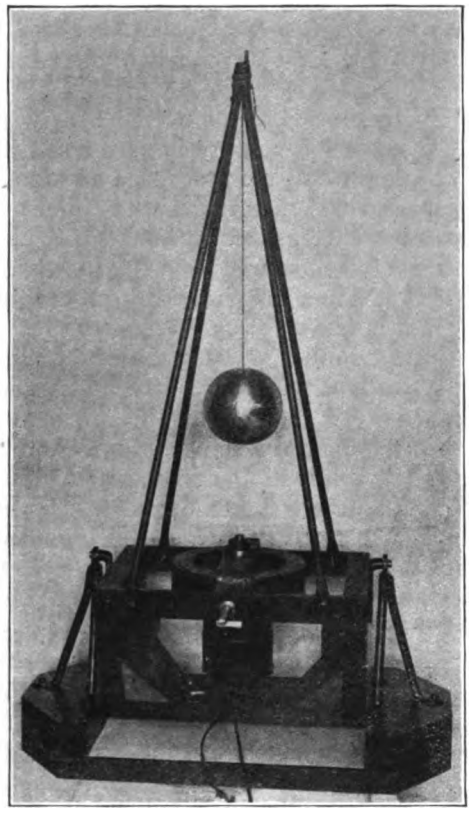
In the following discussion the case of the application of the passive type to the steadying of ships will be taken up in detail, and a partial mathematical treatment undertaken.

The first attempt to steady a ship was made by Sir Henry Bessemer in 1874 when the Bessemer Steamship Company was formed for the purpose of constructing a steamer with a saloon swung on trunnions, and moved relatively to the ship by hydraulic means in such a way as always to keep a level floor no matter how the ship rolled. The hydraulic cylinders were to be controlled by means of a gyroscope but the mistake was made of preventing precession; thus the gyro did not respond to the rolling of the ship and act as a controller. That this would be so was pointed out by Mr. Macfarlane Gray who also pointed out the remedy—viz., let the precession go free. An agreement could not be reached between the Bessemer Company and Mr. Gray for the use of this improvement, so the problem remained unsolved for 32 years, when Dr. Otto Schlick revived it and made a bold step forward in determining to use a gyro not merely as a sensitive element but to use the gyro directly to steady the boat.

Fig. 5 is a photograph of a model of this application made by the writer for demonstration purposes. The wooden cradle swinging on bearings as shown, represents the rolling of the ship. This rolling is caused by holding the pendulum weight out from the vertical and then releasing, the weight thus swinging back and forth in a plane athwartship. By altering the length of the string, waves of different period may be represented. The gyro framework, e. g., wheel, motor, and precessional azle, swings about an athwartship axis—the C. G. of swinging mass being well below the axis of suspension. Underneath there is a small catch which locks the gyro and so prevents the precession. It is sufficient to convince the most skeptical of the

Digitized by Google

magnitude of gyroscopic action, to get hold of the top of the iron framework and try to rock the cradle—first with the catch in place; second with unrestricted precession. In the first place the cradle rocks quite easily as if no gyroscopic action were there; in the second case it is scarcely possible to move it at all. Means are provided whereby the stabilities of the cradle and gyro can be varied at will, and either or both may be made stable, neutral or unstable. The behaviour in each case is very different; this behaviour can be explained mathematically.



In 1906, Schlick showed that it was both practical and commercial to steady a ship by means of a gyroscope. He fitted up the See-bar, a former German torpedo boat, with a gyroscope as shown in model. The wheel was about 3′ 3″ in diameter, weighed 1100 lbs. and made 1600 R. P. M. The drive was by steam, the wheel itself forming a turbine wheel, and steam being led in through the hollow precession trunnions. In a rough sea a roll of 15° on each side of the vertical with precession locked became a total of only 1.5° with precession free to occur. Means are provided for braking the precession hydraulically, this being necessary as referred to later. In subsequent equipments both the drive and the braking are done electrically.

Digitized by Google

Messrs. Swan, Hunter and Wigham Richardson have the patent rights for all European countries except Germany and the first boat they fitted was the "Lochiel," a Scottish pleasure boat. In Germany the first to be fitted with this equipment was the "Silvana," of the Hamburg Amerika Line, plying between Hamburg and German watering places.

Another use to which the gyroscope can be put on board ship—the converse of the above, is to force the precession alternately back and forth, even when there is no rolling tendency acting on the ship. The result is to make the ship roll and thus open a course for itself in pack ice. A vessel has been equipped in this way on the Great Lakes and another in Russia, with the difference that the Russian one had forced pitching instead of rolling.

Mr. Elmer A. Sperry, the inventor of the Sperry gyro-Compass, and the man most to the front in this country in gyroscopic work, has improved on Schlick's method by controlling the precession all the time by a precession engine. The direction in which the precession is forced is determined by a small sensitive gyroscope that answers to very small motions of the boat. The roll is thus anticipated as compared to the more lethargic Schlick system, and the boat can be held in a much more nearly vertical position with a given size of gyroscope. This is known as the Active type of gyroscope and has greater possibilities than the other or Passive type, although evidently more complicated. The passive type will, however, always have a big field due to its greater simplicity.

It is easier to theorise about the active type of gyro because the precession, instead of being the result of the combination of many influences, is directly determined by a separate engine or motor. In analyzing the action of the free precession or passive type it is a little difficult to see why the precession should be braked to get the best results: in fact it appears at first sight that the ship should be held perfectly still if the precession be quite free.

In the preceding proof of $T = I\omega\Omega$ it must be remembered that Ω was considered constant. Imagine the boat in a vertical position and still, when suddenly a torque T is caused to act by the waves. Now if Ω could immediately get up to a value sufficient to satisfy this equation then the torque would be wholly occupied on the gyro and the ship would remain quite still. However, due to the fact that the gyro has considerable inertia about the precession axis, Ω cannot immediately get up to the requisite value so the ship partly rolls under the influence of T though by no means as much as it would if the gyro were absent.

It is evident that the effect of the gyro is to make the ship more reluctant to move: in fact it will be shown later that the net effect, if precession be free, is to increase the inertia of the ship and so to increase the natural period, that is if the gyro framework has itself more than a certain critical amount of stability.

Clearly the gyro does not take any energy of roll from the boat if precession is free. It benefits the boat merely by making the possibility of synchronous wave action less likely. The gyro has no damping action on the boat. If, however, the precession be braked, then work is actually done

Digitized by Google

against this brake and hence reduces the rolling energy of the ship, thus producing a damping effect.

The following mathematical discussion, though deduced to fit the present case, is really further reaching in its results, and could with practically no alteration be applied to any application where there is one body able to vibrate about a certain axis, and a gyro able to vibrate (or precess) about an axis at rt. angles to the first axis.

Notation: I = Moment of Inertia of whole apparatus about axis of roll.

I_g = Moment of Inertia of gyroframework about axis of precession.

m = Moment of Momentum of flywheel = moment of inertia × angular velocity.

a = Weight of cradle and gyro × distance of common C.G. below axis of roll.

b = Weight of gyro of framework × distance of C.G. below axis of precession. Obviously if cradle is made top-heavy, then a will become negatixe; similarly b will be negative if gyro be weighted so as to be top-heavy.

R = angle of roll from vertical position.

P = angle of precession from vertical position.

We can now write out an equation of motion for the roll of the ship and another for the precession of the spin axis. Take direction of R and P such that, as R increases, P tends also to increase.

The speed of rolling is dR/dt; there is therefore a gyroscopic torque tending to increase P, of magnitude m dR/dt; also from the rule previously given, there must be a torque m dP/dt tending to decrease R.

Considering these we get:—

$$I\ d^2R/dt^2 = -aR - m\ dP/dt \qquad (1)$$
$$I\ d^2P/dt^2 = -bP + m\ dR/dt \qquad (2)$$

Differentiating and substituting so as to separate P & R, also writing θ for d/dt we are led to—

$$[II_g\theta^4 + (aI_g + bI + m^2)\theta^2 + ab]\ R = 0$$
$$[II_g\theta^4 + (aI_g + bI + m^2)\theta^2 + ab]\ P = 0 \qquad (3)$$
$$[\theta^4 + (a/I + b/I_g + m^2/II_g)\theta^2 + ab/II_g]\ R = 0 \qquad (4)$$
$$[\theta^4 + (a/I + b/I_g + m^2/II_g)\theta^2 + ab/II_g]\ P = 0 \qquad (5)$$

These are linear differential equations with constant coefficients, the type of differential equations most frequently met with in the application of mathematics to engineering problems.

Digitized by Google

The solution is of the form:—

$$R = A_1 e^{\theta_1 t} + A_2 e^{\theta_2 t} + A_3 e^{\theta_3 t} + A_4 e^{\theta_4 t} \qquad (6)$$

where θ_1, θ_2, θ_3, θ_4 are roots of the equation,

$$\theta^4 + (a/I + b/I_g m^2/II_g)\theta^2 + ab/II_g = 0. \qquad (7)$$

If the roots should come all imaginary then R is a periodic function of time and becomes

$$R = B_1 \sin \theta_1 t + B_2 \cos \theta_1 t + C_1 \sin \theta_2 t + C_2 \cos \theta_2 t \qquad (8)$$

If part of the roots are real and part are imaginary then the solution is a combination of these two.

Obviously there is an enormously wide difference between a solution of type (6) or of type (8). In the former R may increase indefinitely with time, i. e., the apparatus might fall right over. With the latter solution there is a vibration about a mean position which is, of course, a satisfactory state of affairs. With a combination of (6) and (8) there is a progressive falling away superposed on an oscillatory motion.

It has been mentioned that the behaviour of this apparatus is greatly modified as a and b are changed.

Equation (7) will now be studied and the effect on the integral equation (6) and (8) noted, as constants a and b are varied.

Before proceeding further it is as well to look into the limitations of this discussion. In practice the precessional motion is braked for reasons already mentioned; also there is a resistance to the rolling of the ship. These introduce an additional term in each of the equations (1) and (2), which in turn bring in the odd derivatives of R and P in (4) and (5). These add very greatly to the length and tediousness of a complete solution, though, if numerical values be taken in the region of practical application, it will be found that these terms do not alter the type of motion except to introduce damping. Also by keeping this complication out it is much easier to examine the effect of variations in a and b.

Discussion of types of solution:—

Let a and b be both positive, then θ^2 in (7) has two negative values, hence θ has four imaginary values. The solution is therefore of type (8), viz., vibration about a mean position: the influence of friction terms being to successively decrease these swings.

Let a be negative. This is evidently the case of the monorail. Rewriting (7) as $\theta^4 + A\theta^2 + C = O$ (9) we have now C negative and A may be positive or negative. The values of θ^2 are opposite in sign: that is θ has two real values and two imaginary. This means that a solution is a combination of (6) and (8). Verification is easily obtained experimentally for, if cradle be made top-heavy, it vibrates about a mean position that is continually falling away from the vertical.

Digitized by Google

Precisely the same discussion holds if b be made negative. This also is easily verified.

Now what happens if both a and b are negative? i. e., if both cradle and gyroscope are top-heavy—the thing would appear now doubly unstable. In preceding equations, C is again positive and A may be of either sign. There are two cases therefore: (α) if A is positive i. e., if m^2/II_G is $>$ a certain critical value, viz., $a/I + b/I_G$ and (β) if A is negative, i. e., if m^2/II_G is $<$ this critical value. In case (α) the two values of θ^2 are negative, i. e., θ has all imaginary values: in case (β) θ^2 has two positive or all values of θ are real. The conclusion is then that if both cradle and gyro are unstable the whole is stable if speed of wheel be above a certain amount. If not above this certain amount then both will fall away from the vertical.

This can be checked experimentally although the apparatus will not stay up indefinitely. The friction terms that have been ignored cause the oscillation to become gradually greater and greater. If both cradle and gyro be held quite vertical before releasing, then several minutes elapse before the affair falls right over: but if they be released already in an inclined position, then oscillations are at the start considerable and quickly produce overturning. As this friction cannot possibly be wholly got rid of, it is seen that this type of gyroscopic apparatus could not possibly succeed in keeping the monorail-car in balance. In both the Brennan and Schilowsky mono-rail systems this frictional effect is got rid of by a mechanism for artificially affecting the precession. There is, however, a still more important reason for hurrying the precession in a mono-rail mechanism. It is not sufficient that the car remain just as it is in spite of wind or centrifugal force—it must go over in the teeth of the opposition and lean on the wind or inwards in turning a curve as a cyclist does, as in so doing lies its only permanent stability.

To come back to the steadying of ships. The friction in both cases is advantageous. The rolling resistance retards rolling and precessional friction absorbs energy which must come from the energy of rolling—thus putting an additional brake on rolling.

If numerical values be substituted in (7) in the region of practical cases, then the constant term will be found very small compared to the coefficient of θ^2, thus indicating a small value and a big value for θ^2 which, in turn, indicates a quick vibration and a slow vibration. If numerical values are taken in a specific case the amplitude of the quick vibration is practically negligible compared to that of the slow vibration. This can be observed experimentally, for the quick vibration is not at all evident. The net effect is to increase the natural period of roll.

Commercial Prospects of Gyroscopic Applications.

There are engineers today who still do not realize that the gyroscope has ceased to be either a plaything or an ornament for a physics laboratory. There is some excuse for this, as just over a decade ago this was the common belief. Times change however. First in order of commercial importance come the gyro compass and the torpedo. The gyro compass is at present

Digitized by Google

the accepted thing in all navies in spite of the excessive cost. New ships are being fitted and old ones being changed as fast as can conveniently be done. Several of the big liners have also adopted it.

The torpedo—that most destructive of weapons, when it hits—owes its possibility to the gyroscope. Also its weakest point at present is admittedly the directing power.

With the steadying of ships progress appears slower than was anticipated in spite of the fact that fear of seasickness deters thousands every summer from making otherwise desirable trips.

The mono-rail has at present no commercial prospects, though those engineers who dismiss it summarily as something ingenious but fanciful show wonderfully little foresight. One hears the remark "It is all very well going on one rail but who wants to when we can have two?" The ultimate commercial supremacy of the mono-rail for fast traffic depends not on the simpler permanent way (for this would probably be no cheaper) but on the possibility of speed combined with safety. Railroads will never be built without curves, and curves are dangerous because they can be made right for one speed only: a speed smaller than this and the tendency is to jump the rails toward the inside: higher than this and the tendency is to jump toward the outside. A glance at the rails at the Ann Arbor curve will convince anyone of the kind of thing that goes on in rounding a curve at a big speed in spite of speed limit being 40 miles per hour.

A speed of 150 miles per hour is no faster to us than a speed of 70 miles per hour appeared to our grandfathers. Or, to go a step forward and to take the state of affairs in a "Modern Utopia" of H. G. Wells, we find a speed of 200 miles per hour the normal thing for through trains between large centers. These things appear far off, but let one look retrospectively and then think of the present craze for time saving, and the possibilities in electric drive on every wheel and an external form with least wind resistance then it does not appear so unlikely—if the unavoidable curves can be safely negotiated. Herein lies the sole advantage of the mono-rail. Taking a curve of 1000 ft. rad., then at 150 miles per hour, the track must be banked at about 50° to horizontal—at 200 miles per hour this is increased to 70°. Obviously absurd to talk about with a two line track as it would be fatal at any except that particular speed. The mono-rail car would automatically take the precisely correct angle all the time, and the resultant of weight and centrifugal force would go right through the line.

If the public tomorrow demanded a 150 mile an hour service between New York and Chicago, and enterprising capital could be found, then the mono rail is the solution. Two decades hence will probably find one or more such mono rail lines in this country.

Digitized by Google

EXPERIMENTAL REFRIGERATION PLANT AT THE UNIVERSITY OF MICHIGAN

H. E. KEELER, '12 E

It is the purpose of this article to give a description of the experimental refrigeration plant located in the mechanical laboratory of the University of Michigan, both from the standpoint of the plant proper and also the auxiliary special experimental equipment. After this description the work done along the lines of investigation in the field of refrigeration will be taken up, as well as a description of the other lines of experimental work in which refrigeration in general plays an important part and, specifically, how this plant is made use of along present and will be made use of along future lines of experimental testing and research. The plant is designed to operate on the dry compression system which means that no liquid ammonia, which is used as the refrigeraut, is allowed to enter the cyinder of the ammonia compressor.

In making the choice of a refrigerating equipment for the mechanical laboratory many factors entered in which influenced the installation of the present plant. One of the important factors was that the present plant should be readily adaptable to all kinds of investigation along the lines of the mechanical production of cold. It was also very desirable that the plant should be representative of the most modern and standard commercial types. The above statements applied with equal force in the choice of the auxiliary apparatus, some of which is special and much of which is standard apparatus, chosen and installed with general flexibility of use kept constantly in mind.

The prime mover consists of a 20 H. P. single cylinder Murray-Corliss engine, built by the Murray Iron Works Co., of Burlington, Iowa. It has a cylinder bore of 9" and a stroke of 18" and operates at a speed of 90 R. P. M. The valve gear is of the conventioual Corliss, single-eccentric type. The engine is fully equipped with all of the necessary accessories for running complete engine tests of any character, being provided with indicator connections, reducing motion and other minor but essential accessories. It is also provided with a specially designed compensating prony brake, by means of which any desired load up to the capacity of the engine may be steadily and uniformly maintained during an engine test. Steam is supplied to the engine from the university power station at a gauge pressure of 125 pounds per square inch. The exhaust piping from the engine is so arranged that the engine may exhaust into the atmosphere or into a Wheeler surface-condensing equipment which may be operated with or without a vacuum. This condensing equipment furnishes an easy and accurate means for determining the water rates of the engine at different loads.

The ammonia compressor, which is directly coupled to the shaft of the engine, is a double-acting machine of the DeKalb type, built by the

Digitized by Google

Creamery Package Mfg. Co., of Chicago, Illinois, and has a rating of 13 tons of refrigerating capacity. The bore of the engine is 7" and the stroke is 14"; the speed is, of course, 90 R. P. M. This compressor is very representative of the larger compressors in commercial service and affords a refrigerating capacity which is ample for any experimental needs, present or future. The compressor is of first-class construction thruout and is designed for heavy continuous duty. All of its parts are readily accessible. There are two suction and two discharge valves located in each end of the cylinder, and they are so arranged that their faces are flush with the cylinder heads in order to reduce the clearance to the lowest practicable limit. One suction annd one discharge valve in each end of the cylinder are located at the lowest points in order that any liquid ammonia, which might by chance enter the cylinder, may not produce disastrous results. The valves on the compressor are of a special construction which renders them easily replaceable. The piston rod packing-gland is very deep, and the packing is divided into two sections by one lantern or oil gland, which oil gland is connected to the ammonia suction, thus subjecting the outer section of the packing to the suction pressure only. This is usually comparatively low and easily packed against, and makes a tight joint possible without causing undue friction. Uniform pressure on the packing is insured by means of a spiral spring which is compressed by a nut having a fine thread. Piston-rod and cylinder lubrication are effected by means of a sight-feed lubricator feeding oil into the oil gland at the rate of 3 or 4 drops per minute. It is a point worthy of note in ammonia compressor operation that only a high grade of ammonia compressor oil should be used, and that very sparingly. The cylinder and cylinder heads are very thoroughly water-jacketed for the purpose of getting efficient compression, keeping the cylinder valves and piston-rod cool, and making lubrication satisfactory. The event of cutting or scoring, it may be easily replaced. The ammonia suction manifold is provided with a strainer for intercepting scale, thus preventing any liability of the compressor cylinder becoming scored by foreign matter entering it. The ammonia compressor cylinder is provided with two by-pass valves for the purpose of pumping out the ammonia from the high pressure portion of the system or for equalizing the pressure on the high and low pressure sides of the system to facilitate starting. Therometer wells are also provided in which in insert thermometers for determining the temperatures of the ingoing and outgoing cooling water. The compressor is also fitted with indicator connections, reducing motion and all necessary accessories for making complete tests of its operation.

The auxiliary equipment of the plant will next be considered, and in order to get the functions of the various parts of the equipment clearly in mind, the ammonia measuring receiver will be described first. This is an assembly of two vertical cylinders and one inclined cylinder, all of which are capable of withstanding heavy pressures, each being provided with a guage-glass so that the level of the ammonia liquid

Digitized by Google

in each may be readily determined. The ammonia receiver serves as a storage reservoir for the liquid ammonia and also affords a means for determining the amount of the liquid handled during a test. The middle inclined cylinder is calibrated and provided with suitable valves necessary in determining the amount of liquid ammonia, and it is further provided with a well in which to insert a thermometer for determining the temperatures under which the liquid ammonia is measured. The liquid ammonia is then conveyed from the bottom vertical cylinder through high pressure piping to a specially designed valve, capable of giving a very fine control of the liquid flow and known as an "expansion-valve," and thence to a brine-cooler of the double-pipe, counter-flow type. The liquid ammonia, after passing the expansion valve, flows into the outer set of pipes of the brine-cooler and into a region of reduced pressure, thus producing the refrigerating effect desired with the consequent vaporization of the ammonia liquid and absorption of heat from the brine which is circulated through the inner set of pipes. The outer set of pipes are known as the "expansion-pipes." The double pipe construction is used because of its compactness, durability and accessibility. It consists of a series of standard lengths of pipe, each length having within it a pipe of the same length but of smaller diameter, the whole series of pipe lengths being so joined by special return bends at their ends that there is no liquid flow between the outer and inner sets of pipes, and thus two distinct circuits are formed. The one through the inner pipes is for the brine and the one through the outer pipes for the ammonia. It is thus apparent that the only heat interchanges which can take place between the ammonia and brine must be through the metal pipes themselves. The outlet from the expansion pipes is connected to the suction line leading to the ammonia compressor. This suction line is provided with all necessary thermometer wells and valves and is very thoroughly insulated with cork pipe covering of the highest grade. This is to prevent the absorption of heat by the cold ammonia vapor on its way to the compressor. After the ammonia vapor has been compressed in the compressor cylinder it is discharged into a discharge line leading to the outer set of pipes of a double-pipe, counter-current ammonia condenser. This pipe line is also heavily covered with the highest grade of cork covering to prevent loss of heat by the hot, compressed ammonia gas and it is also provided with the necessary thermometer wells and valves.

In the double-pipe, counter-current type of condenser and brine-cooler, the liquids move in opposite directions. this has the advantage that in the brine-cooler the coldest ammonia liquid and vapor absorb heat from the warmest brine. In the case of the ammonia condenser the hottest cooling water absorbs heat from the hottest ammonia gas, and the coldest water absorbs heat from the liquid ammonia which collects in the bottom pipes, as well as also absorbing heat from the coldest ammonia vapor. Thus it be-

Digitized by Google

comes apparent that by this system of heat interchange the most efficient conditions of operation are realized. The double-pipe type of heat interchanger has the additional advantage that rapid circulation is easily obtained, and the cooling surfaces thus rendered highly efficient in accordance with the experimental fact that the amount of heat transmitted per unit of area of surface in contact with a liquid, gas, or vapor, increases as some function of the velocity of their flow over the surface. This function of increase of heat transmission is different for each combination of surfaces and fluids, but in all cases the amount of heat transferred per unit area of surface at any given temperature conditions, increases with increased velocity of the liquids, gases or vapors over them.

In the ammonia condenser the the highly heated and compressed ammonia gas is discharged into the outer set of pipes in order to use air cooling as much as is possible and thus economize on the amount of cooling water which is taken from the city water mains. This cooling water flows through the inner series of pipes and after being metered by an accurate Detroit meter, manufactured by the Central Station Steam Supply Co., of Detroit, Mich.; it is then discharged into the sewer. Thermometer wells are also provided in which to insert thermometers for obtaining the temperatures of the ingoing and outgoing cooling water. All valves necessary for controlling the amount of cooling water flowing are provided. As the hot ammonia gas is cooled and condensed to liquid ammonia, it flows to the lower pipes of the condenser, where it is still further cooled, and from there it flows to the top cylinder of the ammonia measuring apparatus, from there to be measured and used over again.

The next part of the plant which will be considered is the equipment pertaining to the brine circuit. The brine used in this plant is composed of calcium chloride, $CaCl_2$, dissolved in water. A stock of brine is kept on hand which has a specific gravity of 1.294; 30% of salt by weight and a freezing point of -54.4 degrees Fahrenhiet; in other words, it will not freeze until 86.4 degrees Fahrenheit below the freezing point on the Fahrenheit scale, which is at 32 degrees. It is thus apparent that the plant is capable of producing a supply of brine for experimental purposes at a very low temperature. The freezing-tank, which will be described later, is provided with a much greater quantity of brine of approximately 1.024 gravity, having 3% of the salt by weight and a freezing point of 12 degrees Fahrenheit or 20 degrees Fahrenheit below freezing. This brine is used in icemaking and where a brine having an extremely low freezing temperature is not required.

The brine is circulated by means of a Gould single acting triplex pump, which is geared to a 200 volt, direct-current motor of General Electric make, shuntwound and with a speed range of 550 to 2,200 R. P. M., power for which is supplied by the university power station. The brine pump discharge is connected to the brine-cooler and the brine, after passing through the cooler, passes to a distributing man-

Digitized by Google

ifold, where it may be directed to the freezing-tank, to an electric heater or into a brine pipe line leading to the third floor. Here it is used in refrigerating coils used to produce low temperature in a suitably designed chamber, to determine, experimentally, constants of heat transmission of different building materials under different conditions. Scales and tanks are provided so that the amount of brine circulated may be accurately determined by weighing. Thermometer wells are so placed that the temperatures of the brine entering and leaving the brine-cooler may be obtained. The brine pump suction line is so arranged that brine may be drawn from the freezing tank or from the tank of brine which has the very low freezing point.

In order to have a complete ice-plant a freezing-tank is provided and equipped with 35 ice-cans, each with a capacity of 100 pounds, thus giving a total freezing capacity at one time of 3,500 pounds of 1¾ tons. The compressor, however, is capable of handling a freezing-tank making approximately 6½ tons of ice per 24 hours from water at ordinary temperatures. The brine-tank is made of steel plate and is carefully insulated by air spaces and by standard insulation such as is used in the construction of cold-storage chambers. The compartment containing the brine-cooler is carefully insulated by similar construction and methods.

One of the novel features of the plant is the method of supplying heat to the brine, by means of which the heat is transferred to the mixture of liquid ammonia and ammonia vapor in the expansion-pipes. In ordinary cold-storage practice, the heat in the articles to be refrigerated is given up to the surrounding air, which in turn gives it up to the refrigerating coils, and they in turn to the brine circulating through them. By means of this brine the heat is carried to the brine-cooler and given up to the metal of the inner pipes of the brine-cooler, which in turn gives it up to the mixture of ammonia liquid and vapor in the extension pipes. In ordinary can ice-plant practice the heat is taken from the water in the cans by the brine circulating around the cans and the above process carried out. A slight consideration of the many variables entering in and the opportunities for errors in determining the amount of heat absorbed by the brine will at once make apparent the advantages of having a concentrated source of heat supply to the brine which is capable of very accurate determination as to the amount supplied in a given time. Ease of control is also very essential. An electric brine heater has finally been developed for supplying this heat which gives a very easily controlled and definite heat supply.

The chamber containing the heating elements is made of wood with air-spaces to afford good thermal insulation. This chamber is brine tight and is connected in the brine circuit in such a manner that the brine-cooler, electric heater and brine pump form a closed circuit. The heating elements themselves are of special design and construction and are 6 in number. Each element has 50 feet of No. 32 B. & S. gauge michrome resistance ribbon, ¾ inch wide and 0.008 inch thick, wound around a strip of tran-

Digitized by Google

site asbestos wood, 36" long, 16" wide and ⅛" thick. The edges of the strip of asbestos wood are slotted to allow for the linear expansion of the resistance ribbon when heated.

All bolts passing through the asbestos wood are bushed with built-up mica washers in order to give high insulation resistance to the heating elements. Heavy copper terminals are brought out from each heating element for the purpose of connecting the resistance ribbon to the power circuit. Flexible micanite plate of 0.005 inch thickness is placed between the resistance ribbon and the metal jacket for insulation, after which the jacket, which is made of No. 22 B. & S. gauge galvanized iron, is soldered up and thoroughly tested for leaks. The resistance of the nichrome resistance ribbon in each heating element is 4.283 ohms at 75 degrees Fahrenheit, and when the heating elements are in operation in the electric heater, each one is designed to dissipate 10 K. W. or 34120 B. T. U. per hour. The heating elements are designed to operate at 220 volts and draw 45.5 amperes of current. Power for their operation is supplied by the university power station or by the turbo-generator sets in the mechanical laboratory, or by both sources, as is convenient. To operate the refrigerating plant at its rated capacity of 13 tons of refrigeration at the standard A. S. M. E. conditions of 185 pounds per square inch gauge condenser pressure and 15.67 pounds per square inch gauge suction pressure, requires that electrical power shall be supplied continuously to the electric heater at the rate of 45.7 K. W. At 220 volts this requires a current of 207.5 amperes. In order to provide overload capacity and reserve heating elements, the heater is provided with 6 heating elements, this giving a capacity sufficient to dissipate 60 K. W. continuously. At 220 volts this capacity requires a current of 272.7 amperes and the heat dissipated per hour amounts to 204,720 B. T. U.

Some of the experimental testing for which the plant is well adapted and equipped will now be discussed. Aside from the fact that most all steam driven refrigerating plants in commercial service are equipped with Corliss engines, it was desired to have a representative type of Corliss engine in the mechanical laboratory and this was one of the important reasons for adopting this form of prime-mover for this plant. As stated before, the Corliss engine is completely equipped for testing and may be operated without operating the compressor by merely disconnecting the compressor connecting-rod, thus rendering the engine adaptable for use in any form of engine test.

Many special tests may be carried out with the equipment for determining the efficiencies of the various elements of the refrigerating equipment. The double-pipe, counter-current condenser affords excellent means for determining heat transfer coefficients under various rates of gas and fluid flow, also a study of the conditions resulting from the parallel flow of gases and liquids in double-pipe heat interchangers. Distribution of heat losses and heat absorption in piping systems furnishes a fertile field for further investigation. The refrig-

Digitized by Google

erating plant is used in connection with a specially designed and calibrated refrigerating chamber, the interior of which is kept cooled to any degree desired by means of cooled brine, thus enabling coefficients of heat transmission to be determined for various building materials or combinations of building materials under temperature conditions which are the same as those encountered in actual practice. The application of mechanical refrigeration in various branches of industry is growing very rapidly and the outlook for this field of mechanical engineering is more promising than ever. The whole field of the mechanical production of cold is one of the most fascinating and interesting branches of mechanical engineering.

Digitized by Google

AN AUTOMATIC HEADGATE*

KARL F. KEELER, '15E

The function of an automatic headgate in irrigation is to automatically regulate the flow of a stream of water which is diverted from a source such as a reservoir or canal into a canal or lateral ditch.

The contract, agreement or understanding between an irrigation company and the farmer usually stipulates that the company furnish the farmer a certain number of sec. ft. of water for a certain number of acres of land during the irrigation season, or a certain number of acre feet per acre per season, or a certain number of acre feet per acre per hundred days, or some such stipulation, in which it is agreed that the company furnish the farmer a given quantity of water in a given time. Payment is made on the basis of this quantity.

A headgate is an orifice or notch of limited dimensions which can be opened and closed. Therefore the problem of the irrigation company becomes to deliver a given quantity of water through an orifice or notch of known dimensions in a given time. The ordinary headgate now in use is so constituted that when adjusted the dimensions of the orifice or notch remain constant until adjusted again.

The quantity (Q.) of water which will pass through an orifice or notch in a given time is expressed sufficiently accurately for our purpose as follows: Q. is directly proportional to the area (A) and to the square root of the head $\sqrt{H}$, i. e., $Q = CA\sqrt{H}$. H for the notch equals the distance from the bottom of the notch to the level of the water surface in the source, and H for the orifice equals the distance from the center of gravity of the orifice to the water surface of the source.

Now let us assume a canal from which is being diverted, into lateral ditches, two streams of water, one through a notch, say one foot wide extending from the level of the bottom of the canal to above the water surface in the canal and the other through an orifice say one foot square with its lower edge level with the bottom of the canal. Let the water in the lateral ditches flow away freely. Diagram, Fig. 1, shows how the discharge in sec. ft. varies through these headgates at different depths of the water in the main canal. Now further assume that the water in the canal is 1.8 feet deep and that the water-master desires to divert 5¾ sec. ft. through the orifice headgate and 7¼ sec. ft. through the notch headgate. He will then adjust the gates as described, i. e., the orifice gate to one foot square and the notch to one foot wide.

For various reasons in actual practice it rarely happens, especially in smaller canals, that the water surface at any given point along a canal remains at constant height for any length of time. Now if for any cause whatsoever the water surface in the canal rises or falls say 2 feet it will be seen that the discharge through the orifice will increase or decrease ½ sec. ft. and

* The device described is the invention of Mr. Keeler, and was perfected in both its crude and finished forms in the Hydraulic Laboratory of the University of Michigan.

Digitized by Google

through the notch 1⅛ sec. ft. But ½ sec. ft. equals approximately one acre foot per day, and one acre foot is half enough water for an acre of land during the season.

From this assumed case we can see that the requirements of an automatic headgate are that it shall allow the passage of a constant stream of water regardless of the level of the water surface in the source. It will also be recognized that cheapness, simplicity and durability should be controlling features of the device.

The contrivance first conceived was as shown in Fig. 2 and described below. It consists of two sides of the form shown at A connected by a back B and bottom F, thus forming a pocket accessible to the water from in front. This pocket, or gate as we shall call it, is supported from behind by

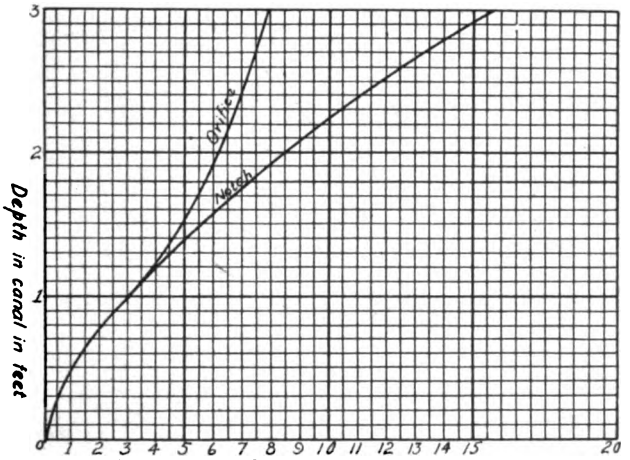


Fig. 1.

four rollers as shown at C, against which the edges D of the gate roll. The rollers C are pivoted to the walls of the channel. The gate is supported vertically by springs as shown at S.

By virtue of the manner in which the gate is supported it will be seen that, if the gate should gradually increase in weight the springs would gradually elongate, the gate would gradually lower, and the size of the orifice under the gate would gradually decrease. This is practically what happens when the water rises in front of the gate.

The bottom of the gate channel is set on a slope sufficient to give the water passing through it a velocity of about 2½ feet per second, so that Q sec. ft. are flowing under the gate when the water is just passing freely under the bottom of the lip L. The gate channel is ⅛ inch wider than the gate so that there is 1-16 inch clearance on both sides of the gate (see Fig. 4).

The gates investigated at the Hydraulic Laboratory of the University of Michigan were set in a channel one foot wide and were to deliver a constant stream of one second foot. Fig. 5 shows a partial section through the

Digitized by Google

Fig. 2.

Digitized by Google

gate along the center line of the channel. The gate was set so that the water just passed freely under its lip when one second foot was flowing. Then the quantity flowing *to* the gate was slightly increased and the surface of the water as it rose struck the projecting lip and piled up in front as shown in Fig. 5. The effect of the contraction caused by the 2-inch vertical lip was found sufficient to compensate for the increased head and Q remained equal to one sec. ft. The quantity flowing to the gate having been slightly increased above one sec. ft. and the quantity passing the gate being kept equal to one sec. ft. the water began to rise slowly in front of the gate. As it

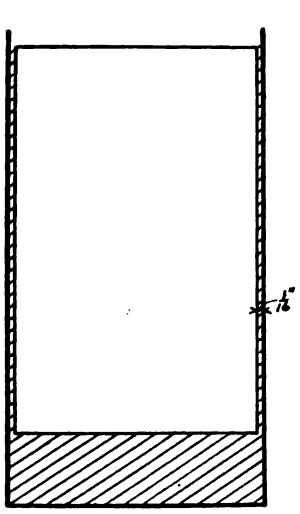


Fig. 4.

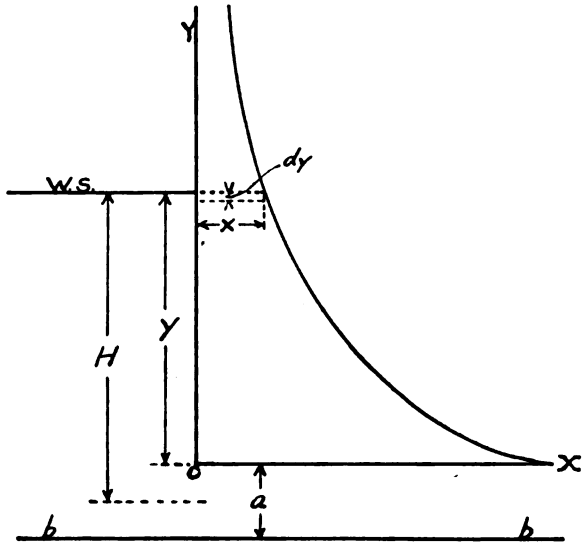


Fig. 6.

rose above the top of the lip it flowed into the gate thus increasing the weight to be supported by the springs, consequently the springs elongated and the gate lowered, decreasing the size of the orifice sufficiently to compensate for the increased head, and Q still equaled one sec. ft. In this same manner the water passing the gate was kept constant as the water rose in front to an elevation three feet above the bottom of the channel. Then the quantity flowing to the gate was decreased slightly below one sec. ft. and the water surface in front of the gate began to lower. As it lowered the weight to be supported by the springs decreased and the gate rose and the area of the orifice was thus increased to compensate for the loss of head. In this same manner the quantity passing the gate was kept equal to one sec. ft. until the water surface in front of the gate was down to the bottom of the lip, i. e., 4 deep in the channel.

It will be seen that the amount the gate lowers per unit rise in head depends upon the amount of water the gate contains per unit rise in head at the given elevation of water surface; but, the width of the gate being

Digitized by Google

constant, the amount of water it will hold per unit rise in head at a given elevation depends on the depth of the gate at that elevation, i. e., the abscissa of the gate curve at that elevation. We must, then, obtain a curve for the back of the gate such that its abscissa at any given ordinate will be proportional to the amount the gate should lower per unit rise in head at that elevation (ordinate). We can obtain this curve mathematically. Referring to Fig. 6 let bb represent the bottom of the channel and YOX the gate hanging in place, WS the water surface, x the abscissa of the gate curve at the level of the water surface, y the distance from the bottom of the gate to the water surface, a the height of the orifice under the gate, H the head on the center of gravity of the orifice under the gate, H the head on the center of gravity of the orifice, L the width of the orifice, V the volume of water contained in the gate.

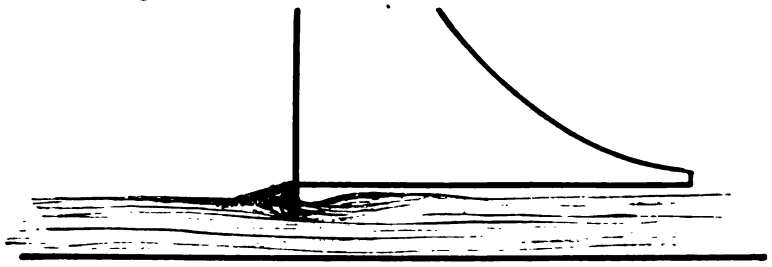


Fig. 5.

Then, since the width of the orifice is constant, we may write in place of $Q = CA\sqrt{H}$, $Q = CLa\sqrt{H}$ and, since Q is also to remain constant, we can combine the constant terms and write

$$a = K H^{-1/2} \qquad (1)$$

Further, the gate is supported vertically in such a manner (by springs) that the change of a will be proportional to

$$x\,dy = -k\,da \qquad (2)$$

We also have

$$y = H - a/2 \qquad (3)$$

Now the equation of the curve we are seeking must be an equation in x and y based on conditions (1), (2) and (3)

From (1)

$$da = -\tfrac{1}{2} K H^{-3/2}\,dH$$

and from (1) and (3)

$$y = H - K/2\,H^{-1/2}$$

then

$$dy = dH + \tfrac{1}{4} K H^{-3/2}\,dH;\ dy = (1 + \tfrac{1}{4} K H^{-3/2})\,dH$$

From (2)

$$(x + \tfrac{1}{4} K H^{-3/2} x)\,dH = (\tfrac{1}{2} K k H^{-3/2})\,dH$$

or

$$x + \tfrac{1}{4} K H^{-3/2} x = \tfrac{1}{2} K k H^{-3/2}$$

Digitized by Google

or

$$-\tfrac{1}{4} K H^{-3/2} x + \tfrac{1}{2} K k H^{-3/2} = x$$

or

$$H^{-3/2}[\tfrac{1}{2} K k - \tfrac{1}{4} K x] = x$$

or

$$H = [(\tfrac{1}{2} Kk - \tfrac{1}{4} K x)/x]^{2/3}$$

and

$$H^{-1/3} = [x/(\tfrac{1}{2} K k - \tfrac{1}{4} K x)]^{1/3}$$

Therefore from (3) we have

$$y = [\tfrac{1}{2} Kk - \tfrac{1}{4} Kx]^{2/3} - K/2\,[x/\tfrac{1}{2} Kk - \tfrac{1}{4} Kx]^{1/3}$$

or

$$y = K^{2/3}\,[(k - 2/3\,x)/2x^{2/3}[x/(\tfrac{1}{2} Kk - \tfrac{1}{4} Kx)]^{1/3}$$

which is the equation of the curve sought.

The curve is seen to depend on the value of K and k.

From (2) we see that $k = -\,xdy/da$ or k equals the change in volume of water in the gate per unit change of *a*, therefore k is the stiffness of the supporting springs, i. e., the weight of water required to cause unit elongation of the springs. Therefore, it will be seen that we can multiply the abscissa of the gate curve by any amount if we also multiply the stiffness of our springs by the same amount. But, by multiplying the abscissae of the gate curve by any number, we multiply the volume of water taken into the gate per unit change in depth-in-gate by the same number. Hence it will be seen that by changing the value of k the value of the two opposing forces—the weight of water in the gate and the force exerted by the distorted springs—is changed. Now in the operation of the gate there is a certain amount of frictional resistance in the rollers which opposes the movement of the gate, and this friction is independent of the value of k. But the two opposing forces—the weight of water in the gate and the force exerted by the distorted springs—which are brought to bear in overcoming this frictional resistance are dependent on the value of k. Therefore the value of k depends on the frictional resistance of the rollers or in other words the abscissae of the gate curve depend on the value of the frictional resistance of the rollers.

The value of K depends on the value of C in the formula $Q = CA\sqrt{H}$ but the value of C varies with the character of the orifice and with the head. The orifice we are dealing with is as shown in Fig. 4. Since values of C for this kind of an orifice are not available it would be necessary to determine them by experiment. A series of experiments were accordingly carried out. But, instead of determining from these experiments the value of C and using equation (4) above for obtaining the gate curve, the following method was used.

The mean curve of a number of sets of independent observation were obtained. See Fig. 7. This curve shows how the gate opening varies with the depth—in—gate, i: e., above bottom of lip.

The change in gate-opening per unit change in depth-in-gate between any two points (elevation in water surface) is proportional to the depth of the gate i. e., the mean abscissa of the gate curve between those points, or, in other words the slope of this curve at any point with respect to the depth-in-gate axis is proportional to the abscissa of the gate curve at that same point.

Digitized by Google

The method folowed in plotting the gate curve from the gate-opening depth-in-gate curve was as follows: In the region of the curve where the difference in gate opening per unit increase of depth-in-gate is the greatest, divide the difference in gate opening per unit increase of depth into twenty equal parts and make a scale A of paper with these twenty divisions as graduations on it. Make another scale B of a length equal to the maximum

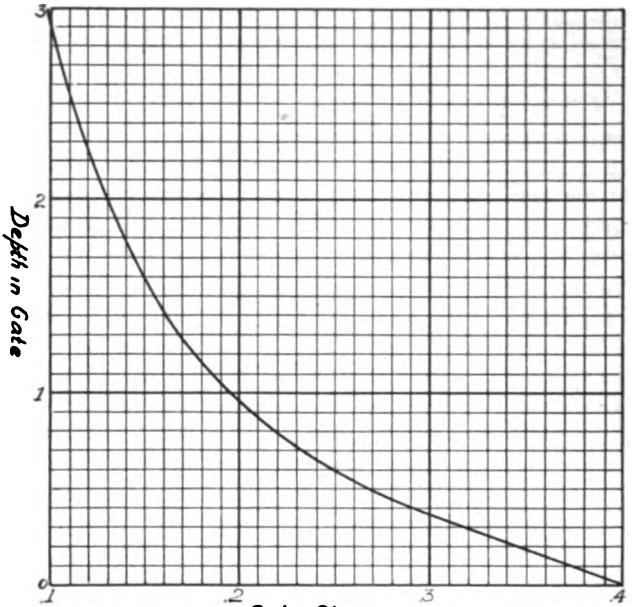


Fig. 7.

gate ordinate desired and divide this scale into twenty equal parts. With A measure the difference in gate-opening between any two points of gate depth and with B lay off the same number of divisions as mean gate ordinate between these two points.

A gate built in accordance with the results of these experiments was tested with the following results:

$Q = 1.026$ sec. ft. maximum variation in flow equals $.0458 \times Q$ or Q remained constant within 4.58%.

Digitized by Google

INCREASING HEAT EFFICIENCY

PROF. J. E. EMSWILER

Notwithstanding the inherently high thermal efficiency of the internal combustion engine, the steam prime mover continues, not only to hold its own, but to advance in development with more rapid strides than its competitor. In this development, both the steam reciprocating engine, and the steam turbine have participated. In the steam engine field, the application of the Uniflow principle to the reciprocating engine, which many engineers had thought to have reached its limit in practical improvement, has offered a new and promising avenue of development. In the steam turbine field, the past year has witnessed the installation of the largest capacity prime mover that has heretofore been constructed, in the 25,000 K. W. turbo-generator for the Commonwealth Edison Co. of Chicago. This will soon be surpassed by the appearance of a 30,000 K. W. unit which is now under construction. This surprising growth in capacity has been accomplished by improvements in design, which have enabled turbine manufacturers to guarantee steam consumption of 11.25 pounds of steam per K. W. per hour, or even less, which is the equivalent of over 25 per cent thermal efficiecy.

The field of usefulness of the steam turbine has been widened by the successful application of gearing of large capacity whereby the speed of the turbine can be reduced. By its use, the turbine has been made available for the operation of direct current generators, belt drives, rolling mill work, and the propulsion of moderate speed ships. It is to be noted in addition, that electrical and hydraulic speed reduction are being used in marine work.

The happy combination which unites the high thermal efficiency of the reciprocating engine in the high pressure steam range, with the high efficiency of the turbine in the low pressure range, is being applied more and more to meet the increased power demands on reciprocating engine plants. The use of the combined unit has also extended to marine work, where the reversibility of the engine presents an additional desirable feature. Complete new installations of these combined units on land have even been reported.

Perhaps the most revolutionary proposition to be offered for the elevation of efficiency of heat engines, since the invention of the steam engine itself, is the proposed binary vapor unit which is being developed by the General Electric Co. The conception is not new, but it has never before been put to actual trial. The fact that a large corporation, with unlimited means and excellent engineering talent, is behind the scheme, offers assurance that it will be given a thorough test to determine its practicability. Should the practical difficulties in handling the mercury be successfully overcome, it is expected that a unit of this type will reach a thermal efficiency as high as 35 per cent or even better, which is a figure difficult to equal, even with a Diesel engine.

Digitized by Google

NEW POWER PLANT OF THE UNIVERSITY OF MICHIGAN

H. I. MARKEY, 1911 E

The new power house of the University, now nearly completed, at a cost of about $325,000, stands as an example of the latest type of power house construction, and takes the place of the now out of date and heavily overloaded plant which has been in continuous service since 1894. Its location, some few hundred feet northeast of the old "cat hole," puts it within easy reach of both the Michigan Central and the campus, and in view of the probable direction of future growth of the University, the site seems well selected indeed. Pleasing to the eye with its dark red brick walls and artificial stone foundations, surmounted by the radial brick stack standing 175 feet above the grates, it is at the same time absolutely fireproof in construction.

PURPOSE OF THE PLANT

It has been designed to produce energy in the form of heat, electricity, and compressed air, in the most economical and efficient manner, and distribute it to the various points of demand. High pressure steam will be required for laboratory use and for the operation of prime movers in the production of electrical energy. Low pressure steam will be required for heating. Hot water will be required for domestic service, gymnasiums, and hospitals. Compressed air will be required for the operation of thermostats in connection with the heating system. Alternating current will be required at 2,300 volts for general distribution, at 110 volts for lighting and at 220 volts for power. Direct current at 125 volts, 250 volts, and 500 volts will also be required.

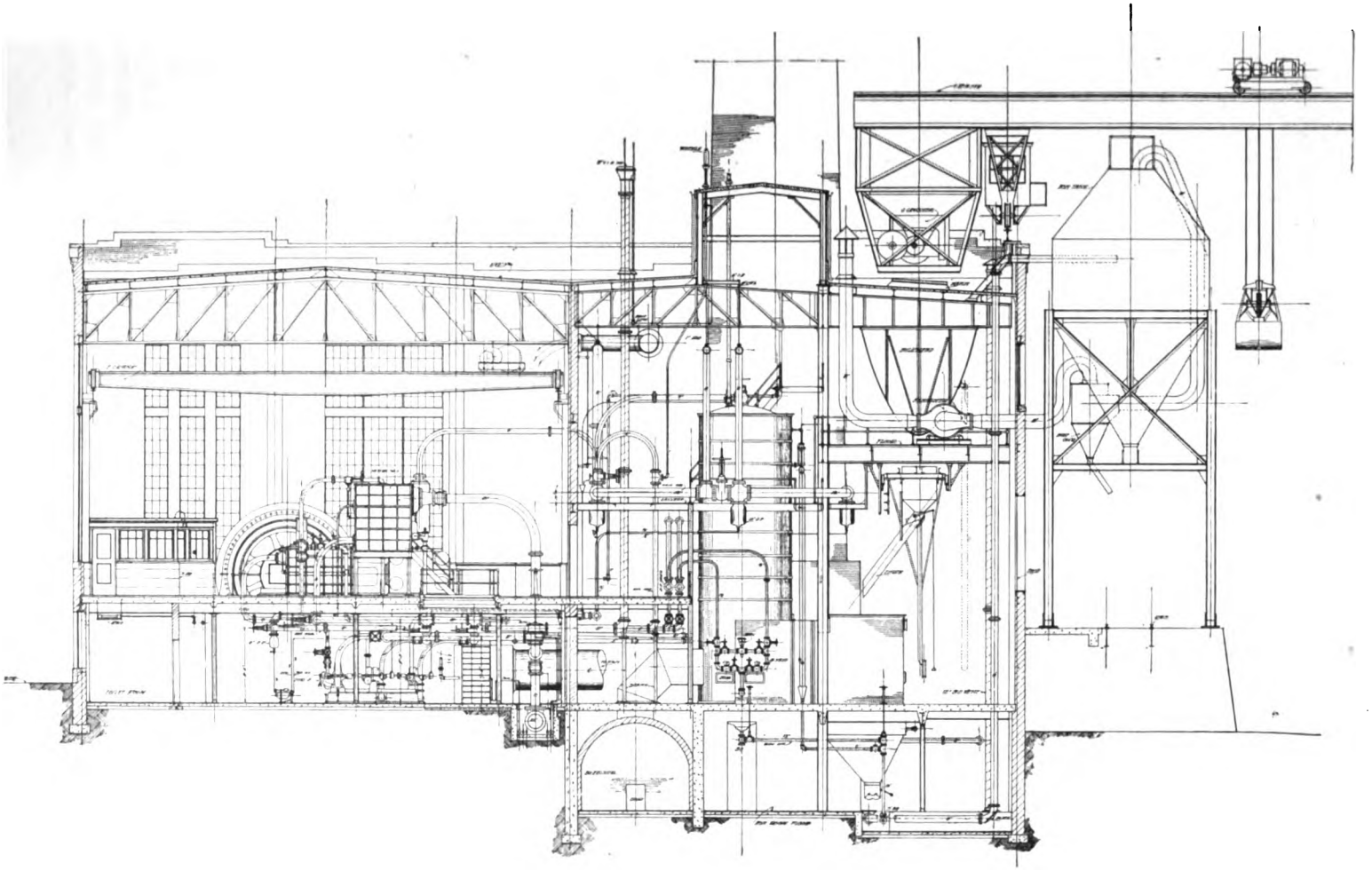
The building proper occupies a ground space of 106′ 6″ by 193′ 6″, and consists of the engine room and boiler room. In addition to this an outside coal storage is provided parallel to the boiler room, and above which the spur track from the M. C. R. R. is elevated, on concrete piers.

THE ENGINE ROOM

The inner walls of the engine room are of a buff colored brick; the lower five feet faced with white enameled tile. The floor is of red tile. Excellent lighting is secured in the day time by large windows on three sides of the room, the sash being of steel, opened or closed by chains from the floor. 400 watt tungstens will furnish light at night. Steel columns encased in brick support the steel roof trusses, crane rails, and the reinforced concrete and tile roof.

The equipment in the engine room at present consists of an Allis-Chalmers cross-compound engine direct connected to a 625 K. V. A. generator, producing 3-phase, 60-cycle alternating current at 2,300 volts.

Digitized by Google



CROSS-SECTION OF POWER PLANT

Digitized by Google

The engine is a non-condensing 24" and 36" by 36" operating at 125 lbs. steam pressure and 120 R. P. M. It is of the double eccentric type, inlet and exhaust valves being separately operated, so that it is possible to carry large overloads. Steam is supplied through a large radius bend sweeping down from the header in boiler room to a separator, and thence to the engine. Foundations for a second similar unit are now in place.

A 150 K. W. motor generator set consisting of a 2,300 volt synchronous motor, and a 250 volt D. C. generator, will convert part of this energy to direct current.

Two 25 K. W. steam turbine driven exciters of the Patitz impulse type running at 3,600 R. P. M. generate current at 125 volts.

The switch board will be located along the east side of the engine room. All transformers and oil switches will be placed in the basement directly below the board. Four transformers will be installed now, three 100 K. V. A. single phase, 220 volt for power service in the power house, and one 15 K. V. A. single phase, 110 volt for power house lighting.

Two 2,000 H. P. Cochrane Open Feed Water Heaters occupy rather a conspicuous place on the main floor, elevated to give gravity feed to the feed pumps in the basement. These heaters will furnish both boiler feed water for domestic service. The Heaters are supplied from a hot well located at the entrance to the tunnel, in the south west corner of the boiler room, and into which all the returns from the campus heating system flow by gravity. Two vertical centrifugal pumps are used for this purpose, each being driven by a Fairbanks-Morse 15 H. P., 2,300 volt motor. Makeup water will be furnished at present from the city mains through a differential valve. Weir type recording meters will measure the total water delivered to the Heaters.

The engine room is heated by hot air drawn through an American Blower Co. 'Vento' Heater by a No. 8 Sirocco Fan and delivered through galvanized ducts, located in the boiler room, to registers in the wall between the engine and boiler room.

A Shaw 15 ton hand operated traveling crane spans the engine room and serves for erection and repairs.

THE BOILER ROOM

Eight 400 horse power Wickes Vertical Water Tube Boilers set in batteries of two each, supply steam at 150 pounds gage pressure. These units are the last word in boiler construction, being erected in steel jacket settings; all drums, heads, man-hole covers and crabs, hand hole plates, etc., being of pressed steel- absolutely no cast steel or cast iron being used in their manufacture. A steel gallery runs along the front of the boilers for the inspection of the water columns and gage glasses. The products of combustion are led into a concrete breeching below the floor, and thence in both directions to the centrally located stack.

Digitized by Google

The latter is of radial brick, 10′ inside diameter by 175′ height above the grates. A hand operated damper in the stack controls the draft. Each battery has a dutch oven front, and is equipped with Murphy Automatic Stokers, driven by a variable speed motor. The boiler stop valves are 7″ Crane Y type Automatic Stop Check Valves, which in case of several tubes breaking and relieving the pressure, automatically close and prevent high pressure steam from returning to the boiler from the header.

The Header is supported on ball bearing rollers on the steel mezzanine floor at the rear of the boilers. Expansion is taken care of by long radius bends. From this header steam is supplied to the power units, feed pumps, etc. A reducing pressure valve serves to reduce the pressure for the heating service.

Two Jeansville Iron Works Co. centrifugal pumps located in the basement serve as feed pumps. Each unit consists of one double stage pump delivering at 160 pounds pressure for boiler feed, and one single stage pump delivering at 75 pounds pressure for domestic service, direct connected to a Terry steam turbine running 2,750 R. P. M. at 120 pounds pressure. A spacer plate enables the domestic service pump to be disconnected at any time and the feed pump run alone. These pumps are fed by gravity from the Heaters directly above them. The boiler feed pumps deliver into two entirely independent lines running along the mezzanine floor in the Boiler Room, from which the boilers are fed, from either line.

ASH HANDLING SYSTEM

The ashes are dumped through the stoker grates into the receiving hoppers below, and are thence carried by suction up into the 12 ton Ash Bunker supported on steel columns and girders over the railroad spur outside of the boiler room. Here they are wet down as they enter. The suction is produced by a General Electric Co. Centrifugal Air Compressor giving a 1.5 pound pressure (or vacuum.) It is direct connected to a 30 H. P. Induction motor running at 3,450 R. P. M. The capacity of the system is 300 pounds of dry ashes per minute. From the Ash Bunker the ashes are deliered directly into railroad cars on the siding below and hauled away.

COAL HANDLING SYSTEM

Coal is to be brought from the M. C. R. R. tracks to the Power House by a 4,000 foot spur track. This track will serve also to haul supplies to the University Store House behind the Homeopathic Hospital. A 30 ton electric locomotive will haul the coal, operating from a third rail at the coal storage end of the line, and from an overhead trolley system the remainder of the distance. The coal will be unloaded by a three and one-half ton electric traveling crane, equipped with a grab bucket, and dumped into either the storage or the bunkers.

Digitized by Google

The outside storage is of 6000 tons capacity. At the power house end of the crane, and integral with it, is a Link Belt Coal Crusher, electrically operated, which crushes the coal before dumping it into the bunkers. The steel coal bunkers are of 325 tons capacity, supported on steel columns over the boiler room and extending the full length of the Power House. From them coal is delivered to an electric traveling hopper, which weighs the charge of coal and dumps it into the stoker hoppers of any furnace desired.

THE TUNNEL

The tunnel connecting the power house with the substation, located between the gymnasium and the medical building, is 1,550 feet long, about 10 feet high, and of concrete. It will contain for the present one 20 inch low pressure steam main, one 8 inch high pressure steam main, one 6 inch hot water main, one 8 inch return main, and a 2 inch compressed air line. All pipes are supported on brackets carrying ball bearing rollers, along the wall. Expansion is to be entirely taken up by the long bends in the pipe at curves in the tunnel; it is the intention to give the pipe an initial tension lengthwise before steam is turned through them. Power cables will be carried in vitrefied conduit below the walk through the tunnel. One 2,300 volt, 3 phase, 3 conductor, No. 2-0 lead armored cable will be installed now.

PROVISION FOR FUTURE GROWTH

The growth of the plant will be taken care of by extending the building 100 feet to the north, giving room for a total of 16-400 H. P. boilers, or 6400 boiler horsepower. A second stack of the same dimensions as the present one will then be erected. Two more 625 K. V. A. generators will be added, one being driven by a Corliss engine, and the other by a steam turbine, with a surface condenser and a cooling tower to be used when the demand for exhaust steam is small. This condenser will be so installed as to be available for testing any one of the units. An additional motor generator set of 150 K. W. capacity, transformers, etc., will be added as necessary.

The water supply will ultimately be obtained by an electrically operated pumping station to be erected near the river, delivering water through underground pipe lines. A water softener will also be installed.

Smith, Hinchman & Grylls, Detroit, Mich., are the architects and engineers for the plant. Mr. H. L. Walton, '08e, assistant engineer for the company, has had general charge of the work. Mr. S. W. Crocker is the resident engineer.

Digitized by Google

THE MICHIGAN TECHNIC

Old Engineering Bldg. **Ann Arbor, Mich.**

OFFICIAL ORGAN OF THE DEPARTMENT OF ENGINEERING OF THE UNIVERSITY OF MICHIGAN

Published quarterly in the months of October, December, March, and May by the Engineering Society

Vol. XXVII MAY, 1914 Number 1

Publishing Staff

OLIVER W. HALL . . . Managing Editor
WM. C. THOMPSON . . Business Manager

Assistants

R. C. Glazier
H. W. Rix
L. C. Rowley
D. M. Flaitz
W. Brodhead
L. W. Lamb
J. C. Abbott
W. S. Helmer
T. D. Weaver
A. E. Hecker
W. M. Riach
F. C. Eisenach
H. Simpson

Advisory Board

PROFESSOR E. M. BRAGG . . . . . Chairman
ASSISTANT PROFESSOR A. O. LEE . . . . . Secretary
MR. H. R. LLOYD . . . . . Treasurer
ASSISTANT PROFESSOR J. R. NELSON . . . Advisory Editor
ROBERT H. BRAUN, '14E . . President Engineering Society

EDITORIAL

THE NEW TECHNIC.

This issue marks the commencement of what the present board hopes will prove a new era in the history of the Michigan Technic. Before undertaking the publication of the present volume, the board investigated thoroughly the conditions surrounding the Technic, in the attempt to determine, if possible, the reasons underlying its failures and successes in the past. As a result of these investigations a new plan of reorganization of both the Technic and Engineering Society was drawn up and approved by the Engineering Society, and passed by the Standing Committee of the Faculty. This issue marks the first appearance of the Technic under the new order of things. A discussion of the plan of reorganization will be found elsewhere.

Several departures and changes will be found between these covers.

The Technic was originally year-

Digitized by Google

ly, then semi-yearly, later quarterly, and finally, last year the attempt was made to publish it monthly. The latter attempt was hardly a success from any viewpoint, in that it took up too much of the time of the students getting it out, mailing the copies and collecting advertising, before the next issue came around. As a yearly or even semi-yearly publication the paper is not a success from a business standpoint, as advertising is difficult to collect for more than one issue at a time. Not only this, but interest is not held up by having it appear so seldom. Therefore, after careful consideration of all these points and numerous others, and in view of the fact that the paper has been most successful when published as a quarterly, the present board offers the Technic as a quarterly as the best solution to this difficult problem.

The cover of the Technic is changed this year, incorporating the table of contents where its logical place should be: on the front cover where it may be first to strike the eye. What is it in a magazine that sells it if not the contents? Therefore, it is hoped that this change from the old order will be approved by our readers, not only because of its usefulness, but because it makes the Technic appear in its true light; that of an Engineering Magazine.

The size of the pages of the Technic has varied from year to year, with no apparent reason. From henceforth, the present size is offered as the best adapted to the needs of the articles used in the Technic, and still keep its size such that it may be conveniently bound into volumes.

From all the changes incorporated in this issue, it may be seen that the ambition of the present board is to standardize the Technic; to put it on a running basis that will not fluctuate from year to year as it has in the past, but which will establish a precedent to be followed by coming boards in years to come, and thus make the Michigan Technic what it should be, and with the hearty co-operation of all, will be: the official organ of the Engineeriign Department of the University of Michigan.

OUR POLICY

The primary function of the Michigan Technic is to act as a bond or cable between the University, with its Faculty and Students, and those who have passed out into the world of Engineering. There is no other medium that may serve so well the purpose of uniting the interests and welfare of the Graduates to their Alma Mater in general, and to their Engineering Department in particular, as the Michigan Technic.

The tendency in the past few years seems to have been to make a strictly technical paper out of the Technic; in this way the Alumni and Departmental affairs have been slighted to a more or less extent. It is the aim of the present board to re-establish the Technic on a firmer footing with the Department and the Alumni; forget about the altogether practical things that a technical paper is supposed to inherit, and strive to make it a publication in which the alumni may

Digitized by Google

find out what their classmates of long ago are doing, what the students of the present day are doing, and last, but not least, what the Department is doing.

The board has done its best to collect all the alumni news of interest that could be obtained, but found that sources were limited. Now that a start has been made, however, help us to keep the columns of the Technic live with news of the doings of the alumni, so that not only the "old boys" can read and enjoy, but so the present generation may learn what the graduates of their school are doing.

The active co-operation of the alumni is extremely necessary in carrying out the policy outlined above. By taking a moment or two sometime to drop a line to the office, giving us some news, some encouragement or some friendly advice, they will be not only helping the men in charge of the Technic, but will be assisting in the formation of a powerful chain between the Alumni and the Engineering Department.

A WORD TO THE ALUMNI

In reading over this issue of the Technic, and after considering all its good points and bad points, do not forget that the success and quality of a magazine are dependent almost entirely on the interest and support that it receives from its subscribers. How many of you who are reading this issue are subscribers? Not very many. How many of you ought to be subscribers? Every one of you, if you have real love for your Alma Mater at heart.

Now, in consideration of the new plan for publication upon which the Technic is basing its fondest hopes for success, and in consideration of the changes that have been made in its make-up, is it not worthy of the earnest support of every one of you alumni? We ask this question, Man to Man! You, who have gone out into the world, have no means of keeping in close touch with the work of the Department. Why not make the Technic that means of keeping old memories fresh and sweet?

Now, if you like this issue of the Technic, fill out the subscription blank enclosed and send it in. If you don't like this issue, send in your subscription anyway, and tell us where to improve the Technic. Co-operation is the secret of success in making the Technic mean what it should to the Engineering Department.

ENGINEERING SOCIETY

Owing to the fact that the final plans for the Engineering Society as a complete whole, including the branch organizations, have not yet been drawn up, it has been thought advisable to postpone its publication until the next issue. The October issue of the Technic will have a complete discussion of the entire plan.

COMPLETE RECORD OF ARTICLES BY FACULTY AND ALUMNI

As one of the functions of the New Technic, an attempt will be made to keep a record of all the articles, papers, talks, etc, written or presented by the alumni and faculty of the University. These will be printed in the Technic for each ensuing quarter, and a complete file kept in the office to which reference may be made at any time.

Digitized by Google

It is desired of the alumni and faculty that they bear this in mind, and keep the Technic informed of any papers or speeches of which they may hear. It is only by this means that the work may be carried out as planned. Copies of articles, reprints, etc., will be appreciated for the file in the offices of the Technic.

PLAN FOR A WORKING FUND

With the donation of $100 by Otto J. Klotz, '72, as a nucleus, a working fund for the Technic has been started. The object of this working fund is to give the Technic a certain capital by means of which it may pull through the times of publication without incurring heavy drains on the Society. At such times all the money is going out to pay for cuts, printing, circulars, letters, etc., and the money from advertising has not yet begun to come in. In order that the Technic may take advantage of cash discounts, it is desirable that there be a certain fund upon which it may draw in times of need. As time goes on, it is planned that a certain part of the proceeds of the Technic will be set aside for such purposes.

Let it be distinctly understood that this money is not going to be used to pay off any debt incurred in printing the Technic. Such is not its purpose, as outlined in the foregoing paragraph.

It is hoped that there may be more like Mr. Klotz who will see their way clear to help insure the Technic at least a fair and square start at each issue, and thus do away with the uncertainty that always accompanys its going to press at such times.

SENIOR ENGINEERS

Soon after this issue of the Technic is off the press, you will be out in the world, working and striving for the glory of your Alma Mater. You will be separated from your classmates made in your four years of study. Would you not like to be able to know that the Technic would be coming to your address regularly, and that it would have news of your classmates; what they are doing; where they are; what positions they are holding? Would it not be worth the price of a subscription to you to know all these things about your classmates? And would you not be interested in knowing what the Department was doing; what new apparatus and buildings it is installing; what its research departments are doing, etc., etc.?

In order that you may have a Technic that will do all these things, and more, for you, it is necessary that we not only have your good faith, but that we also receive your subscription. Try to make it a point to attend to this before you leave Ann Arbor.

The staff wishes to take advantage of the space offered here to thank all those who, by their kindly help and criticism, helped make this issue what it is. The contributors are especially thanked for their articles, all of which are worthy of note.

It is hoped that the advertisers in this issue will receive due consideration and attention from the readers, for, without them, the Technic would not be what it is today.

Digitized by Google

ALUMNI NOTES

Frank C. Emerson, '04 Engineer, formerly a resident of Saginaw, Mich., has been a resident of Wyoming since shortly after graduation. His first location in Wyoming was in the town of Cora, a thriving center consisting of general store, blacksmith shop and a combined ranch- and road-house, located 100 miles from a railroad. Upon his arrival Cora did not appear to be an especially attractive place for an ambitious engineer to start practice, and, from a strictly engineering standpoint, it did not prove to be such at any time later, even though the tributary country was found to be much larger and more resourceful than the trading center would seem to indicate. Work in his chosen profession was not very abundant in the locality, and there seemed but little demand for talents in the engineering line during the fall and winter. In order to occupy his time more fully he accepted an offer to run the Cora general merchandise store during the winter, and this employment, combined with such surveying work as he could drum up from time to time, kept him fairly well occupied until he was called to the State Engineer's Office in May of the following spring.

In outlining his experience at Cora, Mr. Emerson states that it was not without its benefit to him, even though the time seemed rather wasted from an engineering standpoint, for the work at Cora enabled him to gain an intimate knowledge of the new country, its conditions and its people, that could not have been better gained in any other way, and the information was invaluable in connection with his future practice in the state.

After six weeks in the State Engineer's Office, under Mr. C. T. Johnson, now at the University, Mr. Emerson accepted the work of canal and reservoir location for the La Prele Ditch and Reservoir Company at Douglas, Wyoming, spending the summer of 1905 on this work. His first and only experience in railroad work followed, when he was transitman in charge of party on the location of the Saratoga and Encampment R. R., a branch from the Union Pacific, into south-central Wyoming. In March of 1906 he left the railroad work to take charge, for the state, of the location of canals out of the Big Wind River for the irrigation of lands in the ceded portion of the Shoshone Indian Reservation. This location work completed, he returned to the La Prele Ditch, a canal of 250 second-feet capacity designed to reclaim lands west of and continuous to the town of Douglas. This work he left in April, 1907, to take charge of the development work of the Wyoming Land and Irrigation Company in the Big Horn Basin, with which company he is still connected.

Mr. James H. Herron, of the class of 1909, has contributed a very interesting article which will appear in the next issue. He took the degree of Mechanical Engineer and has since specialized in Metallurgical work almost exclusively, holding at present

Digitized by Google

the position of Consulting Metallurgical Engineer, with offices in Cleveland.

He has the unique distinction of being the first to make rolled window sash in this country. He belongs to a number of societies; among these are: A. S. M. E., American Chemical Society, Iron and Steel Institute of Great Britain, American Society and International Association for Testing Materials, Society of Automobile Engineers, and The Cleveland Engineering Society, of which latter he is a director. He is also General Manager of the National Tool Builders' Association.

Previous to holding his present position he was Asst. Engr. Cambria Steel Co., Johnstown, Pa., Chief Engineer of the Burry Compressor Co., Erie, Pa., and Metallurgical Engineer of the Detroit Steel Products Co., Detroit, Michigan.

On account of his wide experience in Metallurgical lines, Mr. Herron's paper should contain some valuable suggestions to the future engineer who is having trouble in deciding what to take up for his life's occupation.

Frank M. Burr has removed from Logansport, Ind., to Cypress, Ind., care of the U. S. Engineer's Office.

Louis D. Brown is connected with the American Steel Foundries Co., of East St. Louis, Ill. He may be addressed at 637 Veronica St.

Edward T. Lazear may be addressed at Wei Hsiev, Shantung, North China, via Siberia.

Ray B. Whitman is connected with the Fidelity Casualty Company, of New York, as engineering inspector, traveling out of Chicago through the central states. He may be addressed care of W. A. Alexander's Sons, Corn Exchange Bank Bldg., Chicago, Ill.

Jacob L. Crane is employed by the engineering firm of Burns & McDonetal, of Kansas, Mo. Address care of the Y. M. C. A.

Walter R Drury is in the City Engineer's office of Flint, Mich. Address 815 E. Second St., Flint. R. D. Van Dyke is in the same office.

H. B. Pickering is a naval architect at Seattle, Washington. Address 101 Grand Trunk Ave.

Hugh H. Thrall is now in the Chief Engineer's Department of Dodge Brothers, Detroit, Mich. He may be addressed at 150 Marston Ave., Detroit.

Roy B. Lapp is associated with the Ingersoll-Rand Co., Rock Drills, of Painted Post, N. Y.

Erwin J. Otis has removed from Brooklyn, N. Y., to Pottsville, Pa., He is connected with the Eastern Pennsylvania Light & Ry. Co., of that city. Mr. Otis is living at the Y. M. C. A.

Harry W. Pabst is efficiency engineer with the Sheet & Tube Co., of Youngstown, Ohio.

William T. Schepeler ic connected with the engineering department of the Carborandum Co., of Niagara Falls, N. Y.

Charles M. Whelan has entered the Reclamation Service with offices at 206 Central Bldg., Portland, Ore.

Paul C. Wong writes that although the home of his family was in the fighting zone at Shanghai, during the recent revolution, the family were warned in time to escape, and the house itself was not seriously injured. His address is Suk Whei Bridge, Outside West Gate, Shanghai, China.

Digitized by Google

George E. Brown is employed as an electrical engineer in Schenectady, N. Y.

Frank M. Burr has removed from Cypress, Ind., to Louisville, Ky., where he is in the United States Engineering Office. Address, Box 72.

Frank C. Gibbs is located at 466 Spitzer Bldg., Toledo, O.

Clair O. Hoover and Theodore O. Warford may be addressed at 83 32d St., New Port News, Va.

Harold G. McGee is assistant engineer on the Ohio State Board of Health. His office address is 303 Hartman Bldg., Columbus, Ohio.

Dean L. Smith is associated with the Hudson Motor Car Co., of Detroit. Address 371 Garland Ave.

Harry E. Frost is teaching in the Department of Science in the Wichita High School. Address, 1205 Larimer Ave., Wichita, Kans.

Leslie M. Harris is connected with the Boston office of the American Engineering Co. He may be addressed at 43 Royal St., Watertown, Mass.

Eli Olmstead is connected with the firm of Stone & Webster, 147 Milk St., Boston, Mass.

Charles L. Lunn has removed from Brunswick, Ga., to New York City, where he is connected with the General Naval Stores Co., 175 Front St.

Elwyn Curtis Balch is employed by the American Telephone & Telegraph Co., 15 Dey St., New York, as an electrical engineer, and lives at 415 West 178 St.

John E. Rogers is auditor for the Ford Motor Car Co., with headquarters at St. Louis, Mo.

Ralph R. Tinkler is employed by J. A. Starratt, Canton, O. Address, 905 Troy Place, N. Y.

William B. F. Hurley may be addressed at 5148 Wayne Ave., Germantown, Philadelphia, Pa.

Wendall T. Meyer is with the Standard Steel Car Co., of Butler, Pa. His address is 235 Amy Ave.

Harold V. Anderson has removed from Manistique, Mich., to Cement City, Mich.

Wilbur L. Casler is director of the Continuation & Industrial School, Superior, Wis.

Wallace S. Heald is associated with the Mississippi River Power Co., of Keokuk, Ia.

Morley S. Sloman is associated with the Sullivan Machinery Co., 30 Church St., New York City.

Ward O. Crossman is a U. S. Highway Engineer and his permanent address is Office of Public Roads, Washington, D. C.

Paul L. Born has removed from Lowell to Worcester, Mass. The Riter-Conley Mfg. Co., with which Mr. Monroe is connected, is building a new gas plant in Worcester, having completed the new plant at Lowell, Mass.

Theodore W. Fowler is teaching in a technical college conducted by the Chinese in Chengto, Szechuen Province, Western China. Mail should be addressed via Siberia, Pekin and Hankow.

Clarence R. Holmes is in charge of the efficiency department of the Reo Motor Car Co., Lansing, Mich.

Arthur Kingston, of Buffalo, N. Y., was nominated by the president and confirmed by the Senate as a second lieutenant in the U. S. Marine Corps on November 11. Lieut. Kingston is stationed at Norfolk, Va., at the Marine Barracks.

Lowell A. Goodman, '67 E., of Kansas City, Mo., is president of the American Pomological Society.

G. Irving Gavett, '93 E., has removed from Seattle, Wash., to Berkley, Cal., where he may be addressed at 2215 Fulton. St.

Will Hazen Boughton, '93 C. E., '98, is treasurer, business manager,

Digitized by Google

and consulting engineer of Vassar College, Poughkeepsie, N. Y. Residence, 348 Church St., Poughkeepsie.

Wilbert S. Drew, '97 E., has accepted the position of supervisor of manual training at Olean, N. Y.

John H. Montgomery, '97 E., '07 E. E., is Associate Professor of Electrical Engineering at the University of Southern California. Mrs. Montgomery was Edith clark of Class '03. Professor and Mrs. Montgomery, with their two children, have been in California for two years, and are living at 1319 W. 37 Place, Los Angeles.

Servius P. Grace, '96 E., is president of the Ak-Ray Corporation, electrical engineers and developers of new electrical devices. He is also president of the Roffy-Grace Corporation, which places on the market the developments of the Ak-Ray Corporation.

Adrian D. Stevenson is a salesman for the General Vehicle Co., Long Island City, N. Y.

Thomas W. Battin, '94 E., has spent most of his time since leaving the University in ship yards in Scotland, where he was engaged in the designing of ships. He is now vice-president and secretary of the Civic Service Corporation, 1326 Chestnut St., Philadelphia, Pa.

Ormond E. Hunt, '97 E., has been recently appointed Asst. Chief Engineer of the Packard Motor Car Co., Detroit, Michigan.

Harry C. Hutchins, '07 E., is an Asst. Engineer in the Department of Public Works, New York City.

Lewis W. Abrons, '08 E., has given up his connection with the Rutland Mfg. Co., of Rutland, Vt., to become associated with the Perth Construction Co., Inc., of New York City, contracting engineers doing steel construction work.

Geo. B. Wheeler, '08 E., is manager of the Textile Works in Brooklyn, N. Y.

Harry L. Coe, '08 E., is a member of the firm of Harpham, Barnes & Stevenson Co., Boston, Mass. They are business economists and production engineers.

Harry D. Edwards, '08 E., formerly with the Buffalo offices of the Linde Air Products Co., is now connected with the New York offices.

Geo. H. Hopkins, '08 E., is representing the American Underslung Motor Car Co., Pittsburgh, Pa.

Fred M. Zeder has recently been appointed to the position of consulting engineer with the Studebaker Co. Since leaving college Mr. Zeder has been employed in the capacity of consulting engineer by a Milwaukee firm and by the Studebaker Co. in the E. M. F. plant, and as head of the chemical and electrical laboratories.

Richard B. May has removed from Cincinnati, and may now be addressed at the Y. M. C. A., Dayton, Ohio. He is with the Dayton Engineering Laboratories.

Frank C. West is connected with the Municipal Electric Light plant of the city of Cleveland. His residence is 908 Nathaniel Road, Cleveland, Ohio.

Robert A. Foreman has removed from Ambridge, Pa., to Detroit, where he is employed by The American Bridge Co., at their Detroit office. Address, 295 23rd St.

Homan F. Hallock has changed his position from chief engineer with the Southern Woods Products Co. to mechanical engineer with the Diamond Match Co. Address, 65 W. Fourth St., Oswego, N. Y.

Roy E. Ward has changed his office address in Pittsburgh, Pa., from 505 Pittsburgh Bank to 2402 Oliver Bldg. Mr. Ward is connected with the Aluminum Company of America.

Digitized by Google

Frank L. Sizer, '78 E., has removed from Palo Alto, Calif., to Dos Cabozosi, Arizona, where he is superintendent of the Mascot Copper Co., operating a mine in southeastern Arizona.

Sydney B. Wight, '78 E., is general purchasing agent of the New York Central Lines, with offices in the Grand Central Terminal of New York. He resides at 380 Riverside Drive.

E. Fred Wood, '79 E., is vice-president of the International Nickel Co., at 43 Exchange Place, New York City.

R. C. Manning, '90 E., is secretary of the American Bridge Co., Ambridge, Pa.

Murray Blanchard, '98 E., '03 C. E., is now with the Sanitary District of Chicago, with offices at 700 Karpen Bldg.

John S. Bennett, '99 E., is deputy commissioner of the Department of Water Supply at 21 Park Row, New York City.

Alfred C. Reed, '99 E., formerly at Elton, Cuba, is now chief rngineer of the Cuba R. R. Co., with headquarters at Camaguey, Cuba.

Robert E. Kremers, '00 E., passed with the highest grade in an examination held to secure an eligible list from which to fill the position ot Chief of Bureau of Highways and Bridges. At present he is the Chief of the Portland Bureau of Inspection.

Henry M. Towar, '00-'04 E., until recently president of the Atlas Belting Co., of Harvard, Ill., is now president of the Acme Belting Co., Niles, Mich.

William O. Houston, '09 E., was on September first appointed Division Engineer of the M. C. R. R. Co., with jurisdiction over the Grand Rapids, South Haven and Allegan Divisions, and the main line from the westerly limits of Niles yard. He was formerly Division Engineer at St. Thomas.

Walter P. Stein, '04 E., has for the past six years been Chief Engineer for three provinces of the Republic of Panama.

Chas. A. Waring, '04 E., is now associated with the National Cash Register Company in Dayton, Ohio.

Santiaga Artiaga is Asst. City Engineer of the city of Manila, and professor of Geometry in Santo Tomas University.

John C. Parker, '01 E., presented a paper entitled "The Industrial Use of Synchronous Motors by Central Stations," at the annual convention of the A. I. E. E., at Coopertown, N. Y.

Wm. C. Hornberger, '01, is superintendent of the Pacific Gas and Electric Company, Phoenix, Ariz.

Carl S. Wagner, '07 E., who has until recently been representative of the American Locomotive Co., in China, Korea and Japan, is now with the company at their New York office. His engagement to Miss Sarah H. Sutherland, '11, was recently announced.

Ralph R. Tinkham, '05 E., who is one of the contributors to this issue, is the Assistant Superintendent of the 11th District, U. S. Lighthouse Service. He is also an associate member of the American Society of Civil Engineers.

J. T. Kingdon, '96, recently accepted a place with the Irrigation Department of the U. S. Department of Agriculture.

Lewis Hill, 8'6, builder of the Roosevelt Dam, has resigned from the government service and has entered into partnership with Quinton & Code, Consulting Engineers of Los Angeles, Cal. Code received his engineering education at the University of Michigan.

H. B. Pickering, '13, has gone into business at 101 Grand Trunk Pacific

Digitized by Google

Dock, Seattle, Wash. He maintains a machine shop and service boat, and acts as agent for the Fulton Mfg. Company, Columbia Brass Foundry Co., L. C. R. Storage Battery Co. and the Rabok Mfg. Company.

Prof. H. C. Sadler, who has been appointed by the government as a representative at the International Commission to determine the load line and safety of vessels, expects to leave for London, during the coming summer. The meetings, which were originally called up for the spring, have been postponed until that time.

Muller Stunts Hay, '02, was recently promoted to 1st Lieutenant, is now executive officer of U. S. R. C. Woodbury, Portland, Maine.

Whitney M. Prall, '06, 2nd Lieutenant Engineers, has served on Onandaga, Thetis, Manning, Mackinac and Seminole. He was recently detailed to special duty at Washington as assistant to contractor.

Ellis Reed-Hill, '12, 3rd Lieutenant Engineers, has served on Itasca, Apache, McCullough, and Bear. He was married in March, 1912. Now is the proud father of a son, born November, 1913.

Gustavus Richard O'Connor, '11, 3rd Lieut. Engineers, has served on Itasca, Apache and Miama. At present he is en route to Thetis, Honolulu. He was commissioned January, 1913, and was previously employed as estimator for the Hull Department, in the New York Shipbuilding Company.

Aaron Matheis, Cadet Engineer, will be commissioned in May.

Van Kammen, Cadet Engineer, will be commissioned in May.

Mayson W. Torbet, ex '11, 3rd Lieut. Engineers, served on Itasca twice, on Winona and on Seneca. He was in command in the Penrose.

H. B. Fenton, '13 E., was recently elected vice-president of the Sarnia Bridge Company.

Henry G. Prout, '70, was recently elected president of the Union Switch and Signal Company, one of the largest companies of its kind in the world.

M. R. Hunter, '13, who went with the maintenance department of the C. & N. W. Ry. in June, left March 1st, to take charge of the Current News section of the Engineering Record, with headquarters at New York.

J. A. Otto was with the construction department of the new steel plant at Duluth from June to September and then went to the Santa Fe Ry. at Topeka as transitman. He attended the convention of the A. R. E. A.

N. K. Sheppard, '13, went with the Saginaw and Bay City Electric Railway with headquarters at Saginaw.

M. L. Mosher, '12, is in the estimating and designing department of the Atlantic Refinery Co., Philadelphia, Pa.

N. L. Van Tal, '11, is now in San Francisco, having been sent there from Panama.

Wendell J. Meyer, '11, is with the Standard Steel Car Co., at Butler, Pa. It is reported that he now has a daughter.

Fritz J. Ruprecht has returned from China, and at present is with the Robins Dry Dock & Repair Co., Brooklyn, N. Y.

R. S. Campbell, '12, is in the office of the Hull superintendent at the Newport News Shipbuilding Co.

Messrs. Maul and Lentz, of the 1911 architectural class, have recently been elected members of the Michigan Chapter of American Institute of Architects. Both men are partners in the firm MacFarlane, Maul & Lentz, of Detroit.

Digitized by Google

DEPARTMENTAL NOTES

WORK OF COLLECTING OLD CLASS PICTURES

During the past year members of the Tau Beta Pi Society have been engaged on the work of securing photographs of the earlier graduating classes in the engineering department. This work has so far progressed that practically complete groups of the engineers of 1865, 1869, 1870 and all classes up to and including 1878 have been received. Photographs copied and mounted, and the framed pictures now hang in the corridors of the engineering building. A number of photos of graduates from 1860 to '64, and '66 to '68, have been received but none of these groups are complete as yet. Work is now in progress and it is hoped that within the next few months photos may be secured of the classes from '80 to '90 inclusive.

The members of the society would appreciate the co-operation of alumni who have class albums or group pictures of the engineering graduates of any year. The loan of these pictures is requested. The time necessary for making copies is not very great, and in every case except one, pictures that have already been secured have been loaned.

In addition to the old class pictures taken at the time of graduation, excellent late photographs of large size have been secured of several of Michigan's eminent engineering graduates. Such pictures now are hung of Alfred Noble, Cornelius Donovan, Geo. Y. Wisner, Charles F. Brush, E. S. Wheeler, A. A. Robinson, S. W. Robinson, J. B. Johnson, R. C. Carpenter. Otto J. Klotz, Benjamin Douglas, and other eminent engineering alumni.

It is the hope of Tau Beta Pi that this collection may be added to so that not only all of the old class groups may be secured, but that many more of the great engineers among our graduates may be given place on the walls.

The University is becoming so large that in no other way can the student body come to know about Michigan men and their achievements. This place cannot but be a good thing for the students. They must inevitably be filled with enthusiasm for their work and with enthusiasm and love for Michigan as they come to know of the great achievements of the older alumni, and of the great places they have filled. The alumni of this department have had their share in the work of the world. We have many of the master builders among our alumni. This movement certainly will bring the students into much closer touch with the alumni and their work.

AUTOMOBILE ENGINEERING

With the establishment of four courses in Automobile Engineering, the Engineering Department of the University of Michigan has taken the lead among technical schools in the country in the development of this latest and most widely interesting branch of Mechanical Engineering. At the beginning of the present year a group of four courses was announced, as electives for senior and junior students as follows:

1. Gasoline Automobiles; three hours. A general course covering the fundamental principles of automobile operation and design, and their application in current automobile practice.

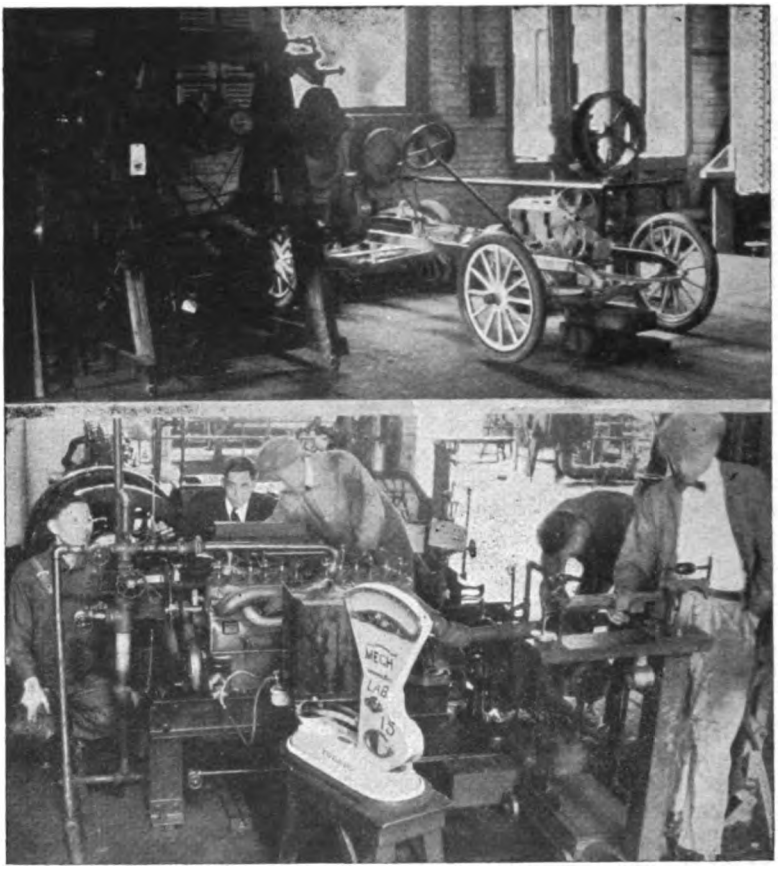
2. Motor Design; three hours. A course covering the theory and design of the complete automobile power plant.

Digitized by Google

3. Chassis Design; three hours. A course covering the theory and design of the automobile chassis with the exception of the motor.

4. Laboratory Testing Course; two hours. This course is for experimental laboratory study of modern automobile motors, with tests on horse power developed, fuel consumption, tuning, efficiency, etc.

Interest among students in both the engineering and literary departments has been great from the start, and outside inquiries indicate that about a dozen will enter the University next year for the purpose of specializing along automobile lines. The general course and the laboratory testing course were given both semesters, with a total enrollment of 85 in the former and 26 in the latter course. Next year the two design courses will also be given, and an advance laboratory research course, in which students will be encouraged to work out original problems, the solutions of which are of immediate interest to both manufacturer and owner.



AUTOMOBILE LABORATORY

The importance of a complete laboratory equipment for demonstration and testing work was early appreciated, and the generosity of automobile manufacturers throughout

Digitized by Google

the country in sending motors, carburetors, transmissions, axles, and even complete chasses has, in one year, placed the Michigan laboratory ahead of any in the country for the study of the modern gasoline automobile. The following equipment has already been installed:

1914 Hudson Six 54 motor and Delco self starter.

1914 Ford Model T. motor.

1914 Reo the Fifth motor.

1911 Franklin air cooled motor.

1911 Krit motor.

1908 Franklin motor.

Complete Studebaker cut-out show chassis.

Timken front and rear pleasure car axles.

Timken front and rear truck axles and transmissions.

Weston-Mott pressed steel rear axle.

Complete Bosch magneto ignition outfit.

Eisemann magneto and switch.

Schebler, Rayfield, Zenith carburetors in cut section.

Spicer universal joint shaft.

Covert selective transmission.

Franklin multiple disc clutch.

Grant-Lees differential.

In addition to this list, the H. H. Franklin Co. has promised a 1914 six cylinder, air cooled motor, and the Packard Motor Car Co. has agreed to send a complete 1914 "38" chassis.

For its standard tests, the laboratory is equipped with prony brakes, water dynamometer brakes, fuel measuring devices, special cooling regulating system, pyrometers, exhaust gas analysis apparatus. Before the end of the present semester, a special Diehl electric cradle dynamometer will be installed which will make the laboratory testing equipment as complete as any in the country. The dynamometer, which is the same as the well known installation at the Automobile Club of America Laboratory in New York City, except that it has greater flexibility, will be rated at 60 horse power and guaranteed for a speed range of 500 to 2,400 R. P. M. With the installation of this new equipment, the department will be in position to do testing work of much benefit to manufacturers, inventors, and automobile owners of the state. Already several requests have been received looking toward research work, and tests have been run on carburetors, mufflers, and a special device for injecting steam into the gas mixture.

In connection with the work, it is planned to make trips to prominent automobile factories in the middle West, as well as to have one or more engineers from the active field address the sections. The first semester, the trip was made to Detroit, where the Chalmers and Hudson factories were inspected, followed by an evening at the Annual Detroit Automobile Show. Toward the close of the semester, Mr. O E. Hunt, '97 E., Asst. Chief Engineer of the Packard Motor Car Co., gave an illustrated talk on "1913 Developement" before an audience of more than 250 students and faculty members. His demonstration in the laboratory, following the lecture, of the latest Packard car was an innovation which held the interest of his hearers until well towards midnight.

The courses in Automobile Engineering are in charge of Asst. Prof. W. T. Fishleigh, '02, '06 E., who has spent several years in the engineering and experimental departments of the Packard Motor Car Company, of Detroit, and Mr. S. R. Thomas, '13 E., whose automobile experience has been supplemented by work covering several summers upon two cycle marine motors.

Digitized by Google

An automatic recording gauge for keeping continuous record of the stage of the Huron river has recently been installed by the Civil Engineering Department. This gauge is located on the east bank of the river just below the Fuller street bridge.

The gauge is installed in a circular concrete house, the foundation of which is excavated into a firm gravel foundation to a depth of about five feet below ordinary water surface in the river. The outside diameter of the building is six feet. The foundation wall extends eight feet above the ground wall. It is substantially built, so as to withstand the thrust of drift and ice jams.

The building proper which rests upon this foundation is constructed of colored concrete blocks which were moulded in circular forms of the required diameter. A conical concrete roof covering was used.

A W. & L. E. Gurley automatic gauge which stamps the actual elevation of the water surface at fifteen minute intervals, has been installed. The records may be taken from the gauge when required.

The students of the hydraulic department of the University are making gaugings of the river from the Fuller street bridge, from which a rating course may be computed. With this rating course and the gauge records, a continuance record of the discharge of the Huron river may be had. This method of keeping discharge records is in accordance with the best practice of the U. S. geological survey. The records of the Huron river as obtained by the students will hereafter be contained in the publications of the U. S. geological survey.

TAU BETA PI ELECTIONS

The local chapter of Tau Beta Pi, the honorary engineering fraternity, announced recently the election of sixteen Junior engineers and three members of the faculty to its membership. The elections were based upon both scholarship and personality. The following is a list of the men who were elected, the choice being made from the first one-eighth in the class with reference to scholarship:

John Henry Bateman, civil, Sault St. Marie; Kenneth Stuart Baxter, mechanical, Vandalia; Chester Clare Bockstahler, civil, Detroit; Sabin Crocker, mechanical, Mt. Clemens; Howard Austin Enos, electrical, Jackson; Oliver W. Hall, mechanical, Denver, Colo.; Carl V. Johnson, machanical, Vandalia; Chester Clare Kennedy, chemical, Pittsburgh, Pa.; Ray C. McAllister, mechanical, Knowlesville, N. Y.; Gordon Brown McCabe, electrical, Detroit; Walter Van Cleve Marshall, architectural, Great Falls, Montana; Allen Townsend Ricketts, mechanical, Ann Arbor; James Wilson Robinson, chemical, Sturgis. Bert Arnold Standerline, chemical, Jones, Mich.; Lyon Frank Terry, civil, Rochester, Ind.; Woodward Alfred Warrick, mechanical, Alexandria, Va.

William C. Hoad, Professor of Sanitary Engineering, was elected as an honorary member; and Horace W. King, Professor of Hydraulic Engineering, and Lewis M. Gram, Professor of Structural Engineering, were elected as alumni members.

The initiation was held Wednesday evening, the 25th of March, at which several of the faculty and student members spoke.

A course in Scientific Shop Management is to be offered for the first semester of 1914-15. This is a new departure that has been con

Digitized by Google

templated for some time. Just how to start, and what to do in such a course seems to be a question that can be answered only by starting to do it.

As planned thus far, the work will be entirely practical. The first step will be to make time studies of the regular work as now conducted in the shop classes. The shop work performed by the students will be used as laboratory material. It is intended to later plan a system by which each piece of work assigned to students in the regular shop courses will be accompanied by a complete set of written instructions for its proper performance, and the proper amount of time that should be spent in performing it. After proper inspection, each man will then know from his instruction card, whether his work is above or below the average.

New features will be added as the work develops, resulting eventually in subdivisions and probably in more than one course. The course must be preceded by two courses in Shop practice and two courses in Economics, as indicated in the forthcoming engineering announcement.

The division of sanitary engineering during the year has been preparing a map of the State showing the sanitary features of each of the principal watersheds. On this map the drainage area of each stream is marked out, and the maximum, minimum and average flow of water in the stream is indicated. All cities and villages having public water supplies are shown, and the character of their supplies,—whether from wells, or from lakes or streams,—is indicated by appropriate symbols. If the water supply is taken from a river or lake, the type of purification plant used is also indicated.

In a similar way, the cities having sewerage systems are represented by another set of symbols, together with the nature of the disposal process, if any is employed. To this information is added data concerning other sources of river pollution, particularly in the case of those streams used for public water supply purposes. If the sewerage is purified before being discharged into the stream the nature of the purification process is indicated.

Taken as a whole, the map shows in a clear and comprehensive manner the chief features of the sanitary situation upon each of the principal water sheds of the state. It marks the beginning of a thorough-going sanitary survey of the waters of the state which the division hopes to push forward to completion as vigorously as opportunrty offers.

The division of sanitary engineering is about to begin a series of tests on the strength and other qualities of sewer pipe and drain tile sold in the state of Michigan, and of other forms of construction used for sewerage purposes. It is a matter of common knowledge that vitrified clay sewer pipe, like other clay products, depends for its strength and durability upon the combination of high class raw materials and excellent methods of manufacture. Lacking either of these the product is likely to be of poor quality. There is oftentimes a good deal of misapprehension on the part of city engineers and other city officials as to the relative value for sewerage purposes of different materials, and also of different shapes and details of design with the same materials. It is the purpose of the division to make an experimental investigation of some of these matters and to publish the results in the form of a bulletin, for the use of city engineers and other officials having to do with sewerage and drainage problems.

Digitized by Google

The apparatus for making certain of these tests—notably the crushing test—is now about ready for use and it is expected that the investigation will be carried forward vigorously during the coming spring and summer.

The Jones & &Lamson Company, of Springfield, Vermont, will shortly place in the engineering shops one of their flat turret lathes, for demonstrating modern methods in lathe work to engineering students.

This lathe, probably the most famous of its kind, is the invention of James Hartness, the president of the Jones & Lamson Company. It has always been in the lead among the highly developed modern machine tools that have made possible the present great volume, high degree of perfection, and low cost, of machinery and mechanical appliances. The Jones & Lamson Company devote their entire resources to the perfection and manufacture of two sizes of this one machine.

To enable purchasers and users of their lathes to secure the best results from them, they employ experts to go from shop to shop, instructing employers and employees in the proper operation and use of their lathes. One of these traveling experts will include the engineering shops on his circuit, appearing here at intervals to give such instruction and demonstrations to shop teachers and students.

The following apparatus has been added recently to the Electrical Laboratories:

1—Cooper Hewitt automatic starting mercury arc lamp with flourescent reflector for color correction.

3—Gas filled tungsten lamps, new high efficiency types, giving double the light of the former tungsten lamps for the same power consumption.

1—Two H. P. electric automobile motor, 60 volts, D. C.

1—Wagner type BK unity power-factor motor, 2 H. P., 220 volts.

1—Motor Generator set, consisting of a 7½ KVA, 3 phase, 220 volt Fort Wayne alternator coupled to a 15 H. P., 220 volt D. C. motor.

1—Crocker Wheeler balancer set for three wire D. C. circuit rated to take 25 amperes on neutral wire, 115-230 volt system.

1—Sharpe-Millar portable universal photometer, for making illumination surveys in interiors and out of doors.

1—Quartz tube mercury arc lamp, Cooper Hewitt, 220 volt, 750 watt.

1—Kimble single phase series alternating current motor 1 H. P., 220 volt.

15—New measuring instruments.

A New Baseball Current Meter and a Dietzgen Hydrometric tube have been added to the equipment for hydraulic students.

The following new apparatus has been added to the Mechanical Laboratory this year.

A Rumely 15-30 tractor was added in the fall. The department has been conducting tests and are well pleased with the results shown.

A Carbon Dioxide recorder, to be used in stack gas analysis, was purchased from the Precision Co.

Additions have also been made to the automobile equipment. In the last year the Studebaker Co. has placed in the laboratory a chassis (complete). The Hudson Motor Car Co. has furnished one of their six cylinder 54 horse power motors. The Ford and Reo Co's have each placed 4 cylinder motors of 20 and 30 horse power respectively. Several new types of transmissions have been added, as well as many different accessories.

Digitized by Google

The Gray Motor Co. have replaced their 6 horse power machine motor with a 2 cylinder 2 horse power motor.

The students of the Mechanical Department have petitioned the American Society of Mechanical Engineers to become student members of that society.

Professor Walter T. Fishleigh, who has charge of the automobile courses, has been appointed a member of the research committee of the Society of Automobile Engineers. This committee will co-operate with the leading automobile manufacturers of the country in an attempt to systematize experimental research in automobile motors.

Professor Joseph A. Bursley is spending a year's leave of absence in Providence, R. I., where he is studying efficiency engineering with the New England Butt Co.

In the Naval Tank a series of systematic experiments is being conducted to determine the effect of the variation of the principal dimensions of ships upon the resistance to motion. A propellor dynamometer is also being built and is well on the way to completion.

The library of the Architectural Department has had many new portfolios and other valuable books added to its splendid collection. Several new casts were also secured for the freehand drawing department at the beginning of the year.

Quite recently an exhibition of Beaux Art designs and sketch problems, from various ateliers and Architectural Schools, was held in Memorial Hall. They were extremely valuable for comparison of different school methods and for the inspiration of the students.

The Architectural Department is helping to promote a state movement to improve the teaching of drawing in the public schools. It will be accomplished through the inspection of this work, the same as is done in other branches.

All those interested in the modern illumination of drafting rooms should visit the Architectural Department. The lighting has been tried by several methods until it has reached the present stage of satisfaction.

The Architectural Department is carrying on extension work in Detroit. Numerous architectural draftsmen are taking advantage of this atelier and are studying architectural design. The Detroit architects have requested the additional teaching of architectural history and building construction.

The wireless course as offered here has proven more popular this year than ever before. The whole equipment has been overhauled and an entire new switch board has been put in.

For the second consecutive time, Professor E. Lorch, of the Architectural Department, has been made vice-president of the Association of Collegiate Societies of Architecture. Fourteen schools, including the large universities of the country, were represented at the meeting of the organization held in New York in January.

Professor Alexander Ziwet and L. A. Hopkins have published a book entitled "Analytic Geometry and Principles of Algebra," which is intended for use in freshmen classes in Mathematics.

A series of tests were conducted from the car in the naval tank calibrating the meters used in determining current flow. By means of propellers attached to the car an accurate test can be made of the meter which in turn is used in estimating the rate of current flow in a stream of water.

Digitized by Google

GENERAL INDEX TO PUBLICATIONS OF THE ENGINEERING SOCIETY OF THE UNIVERSITY OF MICHIGAN.

Selected papers.....1882-1885 (inc.)
The Technic.....1888-1902 (inc.)
The Michigan Technic.....1903-1913 (inc.)

Up to the year 1905 the above papers were published annually. Beginning with the year 1905, the Michigan Technic has appeared twice a year, four times a year, six times a year, and appears again this year as quarterly.

ARTICLE	YEAR	NO.	PAGE
A Few Reflections. W. G. Salter, '95	1904		84
A Talk to Mechanical Engineering Students. E. S. Reid, '93	1906	1	43
Advertise, Why Engineers Should. G. H. Gibson, '99	1903		39
Alternating Currents, Some Points About. Professor H. S. Carhart	1890		66
Aluminum Carbon Cell. R. P. Jackson, '02	1904		99
The Metallurgy of. J. W. Langley	1893		21
Tests with Foundry Iron and. C. G. Taylor	1892		84
Anchor Ice. C. W. Hubbell, '93	1903		17
Annual Spring Trip. Raymond B. Hosken	1910	2	67
Arches, Reinforced, Empirical Formulas for. D. B. Luten, '94	1905	2	7
Metallic Parabolic, Hinged at Crown only. Professor C. E. Greene	1891		47
Architectural Engineering. J. K. Freitag, '90	1891		28
Architectural, Factory and Warehouse. A. K. Adler, '94	1903		11
Armature Reactions. F. C. Wagner, '85	1891		21
As Related to Electrical Design. F. C. Wagner, '85	1898		34
Artificial Lighting by Electricity, Theory and Development of. Prof. Geo. W. Patterson, S.B., Ph.D.	1911	1	4
Asphalt Paving Mixtures, Inspection and Control of. L. Kirschbraun	1908	1	1
Automobile Built in the U. of M. Shops. ————	1912	1	109
Barton Plant. ————	1913	5	7
Base Line Measurement. A. H. Bennett, '02	1904		79
Beams, Deflection of. Prof. A. E. Green	1910	2	21
Belting, Notes on. G. S. Williams, '89	1890		116
Bicycle Design, Some Essentials of. E. H. Ehrman, '88	1897		84
Biography. Allen, Professor John R.			
By Professor H. C. Sadler	1906	1	8
Atkins, Chas. Gilman, '93	1906	2	19
Brunnow, Professor F. F. E.	1895		14
Carhart, Professor H. S. By Professor C. E. Greene	1892		1

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Biography, Henry Smith Carhart, LL.D. Prof. Geo. W. Patterson	1910	2	1
Campbell, Professor E. D. By A. B. Prescott	1894		11
Campbell, William Wallace. By A. Hall, Jr	1895		17
Cheever, Professor Byron W. By A. B. Prescott	1888		79
Cooley, Professor M. E. By S. S. Walker, '61	1889		1
By Professor J. B. Davis, '68	1904		9
Damon, George A., '95. By Dean M. E. Cooley	1907	2	1
Davis, Professor J. B., '68. By M. W. Harrington	1891		1
By F. C. Wilson, '02	1904		16
Denison, Professor Chas. S. By Professor M. L. D'Ooge	1893		9
Douglas, Benjamin. C. S. Denison	1912	1	1
Gram, Professor Lewis Merritt. ————	1913	3	26
Greene, Professor Chas. E. By H. S. Frieze	1888		1
By President James B. Angell	1904		8
By H. B. Merrick, '98	1904		4
Harrington, Professor Mark W	1895		16
Hibbard, John Denison, '87. By Dean M. E. Cooley	1906	2	14
Higbie, H. H. L. D. Goddard	1911	1	2
Hoad, Professor William Christian. Prof. H. E. Riggs	1913	2	28
Johnston, Prof. Clarence T. J. B. Davis	1911	2	1
Marshall, Chas. A	1889		95
Paterson, Professor Geo. W. By Professor H. S. Carhart	1894		23
Pettee, Professor William H. By Professor C. E. Greene	1890		1
Riggs, Professor Henry Earl. Prof. C. T. Johnston	1913	1	16
Russell, Professor Israel Cook. By W. H. Hobbs	1907	1	1
Sadler, Professor Herbert Chas	1905	1	1
Schaeberle, John Martin	1895		16
Williams, Professor Gardner S., '89.			
By Professor J. B. Davis, '68	1905	2	1
Watson, James C	1895		15
Wagner, F. C., '85. By Professor M. E. Cooley	1894		16
Winslow, Robt. Alexander. By Dean M. E. Cooley	1906	1	11
Wisner, George Young, '65. By Professor G. S. Williams, '89	1906	2	7
By Professor G. S. Williams, '89	1906	2	7
Woodward, Professor Robt. Simpson, '72	1906	2	12
Ziwet, Professor Alexander.			
By Professor W. W. Beman	1894		20
Bituminous Road Binders and Dust Preventers. W. S. Wicker	1911	2	39
Blue-printing. E. L. McAllaster, '89	1888		76
Boiler Brace, Test of a. J. T. Faig	1897		101
Boiler Designing for Special Conditions of Service.			
F. M. Dunlap, '85	1900		14
Economy, Notes Regarding. R. C. Carpenter, '75	1896		18
Boilers, Design of Riveted Joints, for. Prof. J. E. Emswiler	1910	2	6
Boilers, Steam, Care and Management of.			
Professor M. E. Cooley	1883		1
Books for Engineers	1890		88
Bracing, Overhead, With Two Panels of Trussing.			
I. M. Wolverton, '90	1893		42
Braced Frames, partially: Portal Bracing.			
Professor C. E. Greene	1900		6

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Bridge, Construction of Little Calumet River. Benj. Douglas, '82	1897		10
Machinery, Some. E. B. Perry, '89	1890		70
Stresses for Concentrated Loading, a Graphical Method of Computing. John C. Moses, '87	1892		43
Construction, Railroad, Notes on. Henry Goldmark	1898		42
Trusses, The Calculation of Stresses in, by Means of Moment Tables. G. E. Roehm, '87	1890		30
Bridges, Draw, Continuous Revolving. C. H. Lindenberger	1892		36
Bridges, World's Greatest. ————	1913	3	25
Building, A Mammoth. J. K. Freitag, '90	1892		36
Stones. Professor W. H. Pettee	1885		34
Caisson, Pneumatic, Sinking of, Around a Bridge Pier. E. M. St. John, '95	1900		56
Calorimetry, Or Methods of finding the Amount of Moisture in Steam. Professor R. C. Carpenter, '75	1891		6
Calorimetric Method of testing Steam Engines. Professor R. C. Carpenter, '75	1892		53
Cams and Cam Rolls. W. T. Stebbins, '96	1894		58
Carhart-Clark Standard Cell, Test with. T. E. Barnum, '92 and E. A. Cheney, '92	1892		79
Caulking Lead Joints	1890		109
Cement Floors and Sidewalks, Distintegration of. A. H. White	1909	2	18
Cement, Portland, The Manufacture of. R. C. Carpenter, '75	1904		39
Research Work on, at U. of M. Professor E. D. Campbell	1905	2	14
Testing, Practical Points in. D. C. Morgan, '93	1890		105
Cement Testing, Wrinkles for the Novice in. L. C. Sabin, '90	1893		98
Cements, Hydraulic, The Use of. A. Noble, '70	1890		26
Manufacture of. L. L. Stone, '08	1906	1	19
and Raw Material from which they are made. Professor W. H. Pettee	1888		16
Chemical Building, the New. Prof. E. D. Campbell	1910	1	4
Chicago Drainage Channel. Alex E. Kastl, '85	1895		25
Lake Front Improvement, by I. C. R. R. Geo. B. Springer, '90	1896		78
Chimney Capacity. Professor M. E. Cooley	1897		109
Robert C. Stevens, '95	1906	1	65
Temperature of Maximum Draught in a. Robert C. Stevens, '95	1899		60
Straightening a Leaning. O. L. E. Weber, '93	1897		8
Chimneys, The Stability of. R. C. Stevens, '95	1905	2	60
Chuck, Revolving. E. H. Neff, '90	1898		61
Civil Engineers, Opportunities of. Geo. Y. Wisner, '65	1907	1	54
Responsibilities of. C. E. Johnson, '95	1903		51
In U. S. Navy. E. P. Goodrich, '98	1900		1

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Coach, Passenger, A First-Class. R. P. Lamont, '91	1889		39
Coal-Mining in Alabama, From an Engineer's Standpoint. Henry Geismer, '97	1889		36
Coal, Selection and Purchasing of. S. T. Mudge	1911	2	58
Coal Shipping. J. Robert Bazley, '11E	1913	5	20
Compound Stress, Strength of Materials Under. A. E. Greene	1911	3	40
Conductors, Copper, Relative Current Density and Temperature Rise for. E. H. Cheney, '92	1896		106
Electrical, Graphical Method for Determining. Professor G. W. Patterson	1892		25
Electrical, Relative Cost of Iron and Copper as. Professor J. R. Allen, '92	1896		124
Conduit, Electrical, Construction of. G. B. Springer, '90	1898		103
Concrete Construction, Present Status of. H. C. Hutchins	1908	1	25
Concrete Dams and Economical Pressure Pipes for Power Development, Some Considerations in the Computation of. F. J. Lemmerz	1911	3	58
Concrete, The Mixing of. Ernest McCullough, C.E.	1906	1	27
Concrete, Reinforced, Design, Examples of Graphics in. E. P. Goodrich	1909	2	12
Conservation Course in University of Michigan. Dean Cooley	1910	2	64
Reinforced Concrete in Earthquake Districts. L. A. Estes	1912	1	63
Copper Ores, Treatment of Lake Superior. F. F. Sharpless, '88	1893		27
Core Test Drilling on New Lock Site—"Soo". Wilber M. Rice	1908	1	28
Curve Problem, A. H. S. Crocker, '89	1889		90
Curve Problem. H. S. Crocker	1890		97
Curves, Problems in. Job Tuthill, '83	1891		73
Dams, Comparison of Arch and Gravity. F. N. Menefee, C.E.	1913	3	7
Dams and Dam Foundaions, Stresses in. Geo. Y. Wisner, '65	1905	2	22
Earth Dams, Design of. Clarence T. Johnston	1911	2	7
Dams, Flow of Water over. Prof. Gardner S. Williams	1910	2	14
Dams, Upward Pressure of Permeating Water. W. O. Crossman.	1912	1	58
Detroit River Improvement. C. Y. Dixon	1909	2	41
Detroit River Tunnel, Electrification of. W. B. Rennie	1911	3	32
Dimensioning, The Launhardt-Weyrauch Method of. C. G. Wrentmore, '93	1895		101
Dome, Ribbed, Investigation of a. R. G. Manning, '90	1890		35
Dome, Spherical, Stresses in a. A. E. Greene, '96	1905	1	7
Drafting Room of a Bridge Office. R. G. Manning, '90	1900		66
System. Geo. A. Worden	1904		22
Drainage, House. A. B. Raymond, '91	1900		48
Drainage Reclamation, Notes on. Frank L. Bolton	1912	1	49
Drilling, Forces in. W. S. Drew, '97; E. G. Struckman, '97	1905	2	43
Dry Plates, Timing and Exposure of. C. T. Johnston	1912	1	78
Dust Collectors, A Comparative Test. H. S. Wheeler, '06, and A. Carrier, '07	1907	2	9
Dynamo-Electric Machines, Physical Theory of. John C. Parker, '01	1905	1	50
John C. Parker, '01 (Cont'd)	1905	2	71
Dynamo Design. H. R. King, '94	1895		81

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Dynamics of Reciprocating Engines. Professor M. E. Cooley	1888		52
Professor M. E. Cooley (Revised)	1902		9
Economy, Comparative. Professor C. E. Greene	1907	2	24
Electric Energy, Long Distance Distribution of. Elmer G. Willyoung, '88	1888		41
Light Plant, A Modern. Arthur Frantzen, '93	1896		43
Lighting Plant, The. Professor H. S. Carhart	1898		1
Railways, F. C. Wagner, '84	1885		19
Railway, Test of a Long Distance	1896		119
Plants for Small Towns. Alex. Dow	1897		17
Storage Battery Road, Results of Efficiency Tests on the Engelwood & Chicago. Geo. A. Damon, '95	1898		70
Electric Street Railways, Future of. J. R. Bibbins	1912	1	11
Electrical Business, Opportunities in the. Geo. A .Damon, '95	1905	1	11
Subway at the Columbian Exposition. H. G. Field, '93	1893		77
Equipment in our new Navy. Theo. Valdemiroff, '97	1902		77
Machines, An Efficiency Test of. Fred H. Loveridge	1893		35
Electricity in a Gas Plant, Use of. H. G. Field, '93	1899		32
Electro-chemical Equivalent of Silver, A Redetermination of. K. E. Guthe	1899		28
Electrolytic Rectifiers. E. A. Weiland, '04, and O. W. Visscher, '04	1905	2	49
Electron Theory. K. E. Guthe	1903		26
Electrostatic Capacity of a two-wire Cable. Professor G. W. Patterson	1897		98
Engines and Boilers of Str. "Thomas W. Palmer," Tests of. W. A. Livingstone, '89, and E. L. McAllaster, '89	1889		88
Engine Repairs, Some Rapid. G. D. Bradshaw, '04	1905	2	40
Testing, Standards employed in. R. C. Carpenter, '75	1894		90
Engineering Building. H. Baldwin, '93	1892		107
Engineering Building Addition, the New. Prof. H. C. Anderson	1910	1	1
Engineering, New Field For. Harry V. Wann, A.M	1913	5	16
Engineering and Architecture at University of Michigan, Six Year Course in. ————	1909	1	66
Engineering Work and the Public. C. T. Johnston	1909	2	1
The new, for U. of M. Prof. C. S. Denison	1902		1
Congress, The International, at World's Columbian Exposition	1893		102
Department, U. of M	1889		33
Development of the. Prof. C. E. Greene	1896		15
Growth since 1890	1905	2	40
Experiences. Prof. J. B. Davis, '68	1888		5
Facts vs. Credulity. Geo. Y. Wisner, '65	1894		27
Scheme, A Novel. Elezear Darow, '92	1896		105
Engineer, The Division. G. M. Walker, Jr., '91	1893		87
-Constrictor, What is an? G. A. Damon, '05	1907	1	35
Engineer, Geological. Prof. W. H. Hobbs	1910	1	11
Engineer, Value of Modern Language to. Herbert A. Kenyon, M.A.	1913	1	14
Engineer's Contract of Employment. J. C. Knowlton	1908	1	12
Ethics for Engineers. Chas. C. Brown, '79	1896		61

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Ethical Status of the Engineering Profession. Chas. C. Brown, '79	1898		92
Fan Pressures. J. R. McColl	1909	2	33
Fan System, Ventilation and Heating with. ————	1909	2	38
Flexure Testing Machine, The new 85-Ton. H. H. Tibbs, '07	1907	1	67
Forced Vibrations—Critical Speeds. John Airey, D.I.C.	1913	2	20
Forest Influences, Some. Filibert Roth, '90	1905	1	34
Fourth Dimension. Prof. Walter B. Ford	1910	2	42
Fuses, Safety. Chas. A. Pratt	1893		63
Gas Analysis and Gas Engine Tests, The Value of. Alfred H. White, '93	1904		68
Gas as an Illumination Agent. Alfred H. White	1911	2	14
Engine, Discussion on Compounding the. E. B. Mead, '00	1906	1	56
Ignition, Improvements in. J. R. Bibbins, '99	1907	1	63
Temperature Determination of a. M. A. Hall, '04, and C. A. Fuller, '04	1905	1	80
Natural. P. R. Whitman, '89	1889		47
Gear Chart, Bevel. E. H. Ehrman, '88	1894		86
Worm. E. H. Ehrman, '88	1894		83
Geological Survey of U. S. Marcus Baker	1894		32
Geology, The Study of, in an Engineering Course. Prof. W. H. Pettee	1892		72
Gold Ores of the Black Hills, S. D., The Metallurgy of the Refractory. F. C. Smith	1897		103
Governors, Automatic and Throttling. Prof. M. E. Cooley	1889		84
Grand Stand Collapse at Ferry Field, Official Report of. C. J. Tilden	1906	1	84
Hand Welds, Efficiency of. F. N. Menefee, C.E.	1913	4	12
Harbor Engineering, American. Geo. Y. Wisner, '65	1891		50
Heating and Ventilating Plants in Detroit Public Schools, Improvements made since 1898. Ralph Collamore, '97	1902		70
By exhaust Steam. G. S. Williams, '89	1889		95
Steam. Prof. M. E. Cooley	1885		3
A Shop for nothing. E. B. Perry, '89	1893		70
Plant, Central, U. of M. Wm. A. Dorrance, '93	1895		86
Heating System, Ford Motor Co. W. H. Chapman, '01	1912	2	27
System, Yaryan, Plant No. 2. R. Collamore, '97, and C. O. Cook, '98	1898		99
High Speed Tool Steel. J. W. Langley	1908	1	17
Hints and Experiences. G. S. Williams, '89	1889		86
Hoists, Mining, An electric. Fred G. Bulkley, '75	1889		24
Hydraulic Curve of Resistance, The Foundation of our Knowledge of. Prof. G. S. Williams, '89	1899		48
Hydraulic Measurements in American Channel at Niagara Falls. O. S. Zelner	1909	1	56
Hydraulics of Rivers having alluvial Beds. Geo. Y. Wisner, '65	1896		51
Some Phases of. Professor G. S. Williams, '89	1903		1
Hydraulics, Some Phases of. G. S. Williams	1908	1	32
Hydrographic Surveys, Some methods of making. C. Y. Dixon, '87	1897		1
Illumination. Professor G. W. Patterson	1903		8

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Illumination, Design of, With Particular Reference to Interiors. Prof. H. H. Higbie	1911	1	64
Illumination of Streets and Open Places. E. Darrow	1911	1	102
Impulse Wheels, Tests of, at U. of M. Ralph R. Tinkham, '05, J. T. Kingdon, '06	1906	2	26
Impulse Wheels, Type Characteristic of, and its Use. S. J. Zowski.	1911	2	18
Incandescent Electric Lamps, Their Photometry, and Some Data as Regards Their Performance. Leonard J. Lewinson	1911	1	17
Incandescent Lamps, The efficiency of. F. S. Richmond, '91, and J. M. Crosby, '91	1891		75
Injector Tests, Some. E. B. Perry, '89	1889		56
Inspection of Metallic Structures, Notes on. James Sanderson, '78	1883		27
Insulated Wire, Absorption of an. Professor G. W. Patterson	1895		107
Insulation Resistance, A new Method of Measuring. Professor G. W. Patterson	1891		41
Inventions, Shop and Office Practice for the Protection of. D. B. Cheever, '91	1903		42
Iron, Modulus of Elasticity in American Ignot. S. Saulson, and F. N. Menefee	1913	5	13
Irrigation Engineering, Some Practical Points in. R. C. Gemmell, '84	1897		62
Irrigation Investigation. C. T. Johnson, '95	1900		41
System, in Wyoming. C. T. Johnson, '95	1898		26
Jones Set-Up Process. A. E. White	1912	2	35
Kerosene Engine, Test of a. W. A. Detwieler, '02, and L. N. Udell, '02	1904		107
Kutter's Formula and Flow of Rivers. R. L. Sackett, '91	1893		100
Labor Experiments. G. S. Williams, '89	1895		105
Laboratory, Electrical. Professor H. S. Carhart	1892		105
Engineering	1888		87
Mechanical	1889		97
The New Physical	1888		85
Work in Engineering, U. of M	1890		61
Lake Superior Iron Ore Mines. L. D. Anderson, '01	1902		58
Landscape Gardner, A few Words from a. O. C. Simonds, '78	1894		39
Latitude, Variation of. Professor W. J. Hussey	1893		14
Launch, Model Steam, Experiments with. G. E. Stannard, '89	1889		76
Law Hints for Engineers. Geo. W. Lilly, '81	1898		53
Leak, A Peculiar	1890		111
Least Squares, Elements of. W. W. Campbell, '86	1891		57
Light, Redistribution of. E. N. Hyde	1911	1	40
Line, Direction of a. Professor J. B. Davis, '68	1892		14
Line, Direction of a. O. H. Aikiane, '77	1894		35
Loads, Uniform, for Test Beams. C. J. Tilden	1906	1	14
Locomotive Road Test. J. C. Thorpe	1904		56
Longitudes, Transpacific. Otto Klotz, '72	1905	1	14
Lubrication, Friction and. H. D. Burnett, '84	1884		29
Lubricating Oils, Testing of. F. C. Parmenter, '03	1904		92
Machine Design in Steel Works, Points on. C. C. Smith, '86	1890		99
Magnetic Lines of Force. Professor G. W. Patterson	1907	2	35
Marine Engineering	1889		98

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Mathematics for the Engineer, the Use of. Professor A. Ziwet..	1890		19
Measurement, To Transfer a.....	1890		104
Mechanical Idea, The. Professor D. V. Wood, C.E., M.E.....	1894		25
Memorial Exercises.			
Upon the Death of Professor C. E. Greene.....	1904		1
Memorial to Professor C. E. Greene.....	1906	1	1
Mercury Cooper-Hewitt Rectifier. R. P. Jackson, '02.....	1912	2	1
Metals, Endurance Tests of, Some recent German.			
Chas. A. Marshall, '76.....	1889		7
Michigan Engineers in the War.....	1899		63
Union Club House, Plans. Professor J. R. Allen, '92.....	1905	2	71
Mining in General as a Legitimate Business. F. C. Smith, '89.....	1890		52
Moment, Bending, Position of Maximum, on a Beam with Concentrated Loads. Professor C. E. Greene.....	1892		41
Bending, of Pins. Professor C. E. Greene.....	1889		36
Moments of Inertia of a Plane Section, etc. Extracts from "Hutte." G. S. Williams, '89.....	1893		91
Mortars and Cements. Job Tuthill, '83.....	1884		21
Motor, Electric, A Range of Speed in an. F. C. Wagner, '85.....	1895		116
Hydraulic, Tests of. T. H. Hinchman, Jr., '92.....	1893		110
Experimental for Mech. Lab. C. E. DePuy, '91.....	1891		83
Naval Architecture, Experimental Work in.			
Professor H. C. Sadler.....	1902		44
Nicaragua Canal Project, The. F. P. Dais, '76.....	1895		47
Nozzles, Flow of Steam Through. J. E. Emswiler.....	1911	3	50
Nozzles, Flow of Steam Through, Experiments on.			
J. E. Emswiler, and C. H. Fessenden.....	1912	1	89
Observatory, Detroit, of the U. of M. Asaph Hall, Jr.....	1895		9
Overahul. G. M. Walker, '90.....	1889		61
Patent Law, A Treatise on the. Frank J. Seabolt, '97.....	1907	1	4
Pavements. F. M. Dunlap, '83.....	1884		12
Φ (Phi) and its Destruction. W. D. Ball, '90.....	1898		51
Photography, The Genesis of, with Hints on Developing.			
A. B. Stevens	1892		68
Photography, Up-to-date. W. F. Davidson.....	1913	1	5
Pile Driving, Hydraulic, at the Interstate Bridge, East Omaha,			
Neb. C. H. Richmond.....	1894		73
Pipe Coverings, Relative Cost of. Professor M. E. Cooley.....	1896		114
Covering Tests. B. L. Foster, '96, and C. S. Mason, '96....	1896		110
Laying. G. S. Williams, '89.....	1890		106
Costs of. G. S. Williams, '89.....	1895		110
Estimate on. G. S. Williams, '89.....	1895		115
Wooden Stave. R. C. Gemmell, '84.....	1895		34
Pipes, Submerged Water, Desig and Construction of.			
G. F. Fenkell	1903		33
Notes on above. G. S. Williams, '89.....	1889		86
Piping, The Coloring of in U. S. Navy. Notes on.....	1889		67
Pitot Tube for Measuring Air. T. C. Taylor.....	1911	2	51
Plane Table. Professor J. B. Davis, '68.....	1896		88
Plane Table (Cont'd). Professor J. B. Davis, '68.....	1897		36
Plane Table (Cont'd). Professor J. B. Davis, '68.....	1898		4

Digitized by Google

374264A

ARTICLE	YEAR	NO.	PAGE
Plats in Michigan, Town, City and Village. Professor J. B. Davis, '68	1899		9
Pole-Line Construction. Alfred C. Marshall, '93	1895		113
Power Developments at Massena, N. Y. L. A. Whitsit, '05	1912	2	14
Power, Transmission of. A. R. Frantzen, '92	1892		88
By Compressed Air. Professor J. R. Allen, '92	1896		101
Transmission, Electric, Modern Tendency in. John C. Parker, '01	1907	2	39
Power Plant Testing, Professor Moyer's New Book on. J. E. Emswiler	1912	1	111
Power Plants, Notes on the Comparative Efficiency of Gas and Steam. J. R. Bibbins, '99	1906	1	34
Power of Numbers, A Graphical Method of Finding. J. N. Hatch, '92	1892		106
Prime Movers, Relative Cost of. J. R. Allen, '92	1892		99
Protractor Triangle, A. C. E. DePuy, '91	1889		79
Pulley Testing. F. A. Wines, '93	1893		107
Pump, The Blake. E H. Neff, '90	1890		95
The Gordon	1890		110
Pumps, Slip of. G. S. Williams, '89	1889		92
Quebec Bridge Inquiry. (Extracts From Report of the Royal Commission.) Prof. C. J. Tilden	1913	3	19
Radiators, Tests of. D. B. Cheever, '91	1891		81
Radiators, Indirect, Test of. D. R. Fraser, '04, and D. D. Bradshaw, '04	1905	1	43
Railroad Electrification Matters, Some Notes on. C. L. DeMuralt.	1909	1	4
Railroad Work, Construction Profile in. G. M. Walker, Jr., '90	1889		85
Railway Signaling. Dwight C. Morgan	1894		50
System, Economics of a Double Trolley. Elezar Darrow, '92	1896		35
Rainfall, Relation of, to Water Supply. Professor C. E. Greene	1895		76
Rankine's Theory of Earth Pressure, An Experimental Investigation of. F. C. Stevens, '03, and R. D. Goodrich, '03	1904		89
Reading and Indexing. B. L. Green, '91	1896		120
Reminiscences. Frank P. Davis, '76	1899		40
Rees Roturbo Pump. M. R. Blish, '11	1912	2	49
Rivers, Dead. F. C. Smith, '89	1892		29
River and Harbor Works, and the Civil Engineer. H. C. Ripley, '70	1902		32
Roads, Construction and Maintenance of. W. H. Pease	1888		11
Good. D. B. Luten, '94	1897		79
Good, Who shall build them? J. N. Hatch, '92	1904		34
Sanitary Experiment Station, Nature and Purpose of. Prof. W. C. Hoad	1913	3	12
Road Materials, Tests on. Ira T. Hook, '13E	1913	4	7
St. Clair Deep Water Channel. G. I. Gavett, '93	1896		46
Saw, Circular, Horsepower consumed by a. A. L. Becker, '93	1893		109
Sanitary Improvement in the West Wing of Jackson Prison. C. G. Wrentmore, '93	1905	1	26
Schwedler Dome, Loads and Stresses. A. P. Mills	1909	1	9

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Screws. E. H. Ehrman, '88	1903		54
Sewer Pipe Tests. Professor C. E. Greene	1897		56
Notes on the Construction of. H. E. Riggs	1897		71
Sewerage System, The Shone Hydro-Pneumatic at the World's Fair. J. K. Freitag, '90	1893		104
Sewers, Leakage in Sanitary. Prof. E. D. Rich	1910	1	16
Shafting, Notes on Lining	1891		89
Ship Tank, The Experimental, of the U. of M. Professor H. C. Sadler	1906	2	21
Ships, Results of Some Experiments Upon the Resistance of. H. C. Sadler	1908	1	22
Smoke, Consumers, Steam Jet. S. T. Mudge	1910	1	24
Smoke Washing. Geo. E. Wallis	1911	2	35
Soil, The Action on Gas Pipes, Trolley Poles, Cedar Poles, Steam Pipes, etc. G. S. Williams, '89	1895		108
Shrinkage, Rolled in 6" Layers. A. E. Kastel, '85	1902		51
Spark Coils, Time Tests of Jump. W. C. Smith, '05, and J. H. Hunt, '05	1906	1	46
Specifications. G. S. Williams, '89	1890		102
Spring Tests	1890		114
Stand Pipe vs Trestle Tower, Relative Economy for Water Works. H. S. Crocker, '89	1889		70
Steam, Expansion Cures for, Theoretical Efficiencies of Various. F. C. Wagner, '85	1902		47
Machinery, of U. S. S. Yosemite. Professor M. E. Cooley	1899		1
Making, Factors in the Cost of. Professor M. E. Cooley	1896		80
Stamp Foundations at the Isle Royale Copper Company's Stamp Mill. A. L. Burgan, '95	1902		76
Use of Superheated, Results of Experiments by Professor M. F. Gutermuth. Professor J. R. Allen, '92	1897		111
Superheated, In Engines and Turbines, Notes on. J. R. Billins, '99	1905	2	27
Turbine, Impulse Wheel as a. F. C. Wagner, '85	1895		18
Steam Turbines, Low Pressure or "Exhaust". J. A. Moyer	1909	1	23
Turbine, The Present Status of. J. R. Bibbins, '99	1903		72
Steel, Notes on a New Process for Fining. G. F. Key	1896		122
Tool. John W. Langley	1890		5
Stoker, Taylor. J. H. Visser	1912	1	97
Stresses, Composition and Resolution of. J. H. Griffith	1911	3	1
Structural Work, Angles in Skew Connections in. C. G. Wrentmore, '93	1903		44
Structures, Comparative Economy of	1902		37
Switchboard and Panel Board Design and Construction. Arthur Frantzen, '92	1904		26
Subway Construction, New York. H. C. Hutchins	1909	1	51
Summer Camp of University of Michigan, History of. Prof. H. B. Merrick	1910	2	35
Summer Camp. Harold McGee, '13E	1913	5	22
Sun's Distance, The. J. M. Schaeberle, '76	1883		33
Tape, The Long. F. A. Steiger, '91	1889		95

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
Tangential Water Wheel, The Doble, in Hydraulic Lab. C. W. Whitney, '00	1907	1	49
Telephone Engineering. S. P. Grace, '96	1903		47
Exchange, The U. of M. Private Branch. R. D. Parker, '05	1907	2	52
Telephone Currents, Transmission of. S. P. Grace	1909	2	5
Templates and Template Making. J. C. Moses, '87	1896		38
Thermometers, Notes on. D. B. Cheever, '91	1891		88
Topography, Photo. D. B. Luten, '94	1895		22
Tracks, Railroad, Elevation of Ill. Cen. G. B. Springer, '90	1893		73
Track Laying. I. O. Walker, '83	1889		77
Tramways, Aerial. James N. Hatch, '92	1907	2	45
Transformers, Auto. R. E. Wooley, '06	1907	1	28
High Frequency. B. F. Bailey, '98	1903		66
Transit Adjustments and Tests. Professor J. B. Davis, '68	1893		46
Transit Adjustments and Tests. Professor J. B. Davis, '68	1906		26
Transmission Lines, Some General Considerations in the Design of Long Distance. S. B. Wiggins	1911	3	20
Transportation Problems, Graphical Analysis of. Geo. A. Damon.	1912	1	4
Trusses, Hip- and Valley, a problem in. J. N. Hatch, '92	1896		66
Trusses, Theory of Secondary Stresses in. J. H. Griffith	1909	1	31
Tunnel, The Detroit River. Ben Douglas, '82	1907	1	58
Turbines at Niagara Falls, The 5,000 H. P. Professor D. V. Wood	1896		25
Valve, The Lunken Renewable Seat	1904		114
Ventilation, of Houses. J. P. Rusche, '88	1888		26
Vessel Design, Notes on a System of. E. L. McAllaster, '89	1894		77
Voltages, Alternating and Direct, Lamp Method of Comparing. D. P. Cheever, '91	1895		110
Wall, Retaining, for Earth. Professor C. E. Greene	1888		36
Watch Out! Percy H. Richardson, '88	1893		106
Water, Hot, Velocity Flow of, in Pipes and Radiators. J. T. Pratt, '04, and J. R. Mansfield, '04	1905	1	71
Consumption, Notes on. Professor G. S. Williams, '89	1897		28
Water, Supplying Detroit with. A. D. Jamieson, '10E	1913	4	17
Supply—Direct Pressure. G. S. Williams, '89	1889		81
Engineering, Some Practical Points in. R. C. Gemmel, '84	1894		39
Notes. G. S. Williams, '89	1894		112
of Cities. Professor V. C. Vaughan, M.D	1890		77
of large Cities. G. Y. Wisner, '75	1902		53
Tank Bottoms. J. M. Raikes, '96	1896		74
Water Tube Boilers, Comparison of. C. H. Fessenden	1909	2	26
Water-Turbine Runners, Rational Method of Determining the Principal Dimensions of. Prof. S. J. Zowski	1910	2	47
Water Turbines, Introduction to Theory of. S. J. Zowski	1912	1	15
Water Turbines, American High Speed Runners for. Prof. S. J. Zowski	1910	1	29
Works, Detroit, Levelling in connection with. C. W. Hubbell, '93	1898		63
Welds, The Strength of. Professor M. E. Cooley	1896		112

Digitized by Google

ARTICLE	YEAR	NO.	PAGE
White Lead. J. J. Morsman, '93	1898		19
Wireless Telegraphy. Prof. R. D. Parker	1913	2	7
Wrought Iron. R. C. Gemmell, '84	1884		3
at Low and High Temperatures, Strength of. R. C. Carpenter, '75	1898		80
Wood, Preservation of. F. M. Dunlap, '83	1883		16
Work and the Man. John C. Parker	1912	1	102

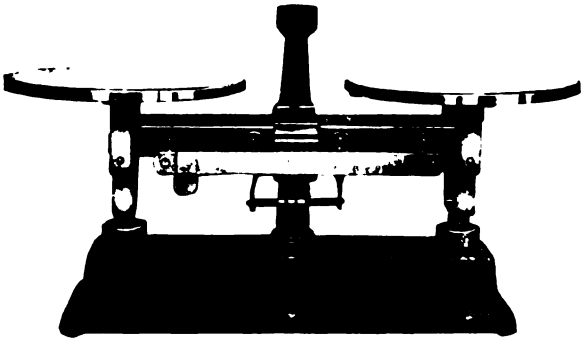
Digitized by Google

"A Word to the Wise is Sufficient"

Five hundred captivating Spring Patterns await your gaze. Take the time, or make the time to see them. Select a becoming cloth and pattern. Let us tailor to measure a suit which will earn the fullest admiration of yourself and friends.

J. K. MALCOLM

604 E. Liberty Street **Malcolm Block**



Laboratory Supplies

Manufactured and Imported by

EBERBACH & SON CO.

Agate Bearing Balance, No. 310
List Price, $6.00

Catalogues Furnished on Reques

JNO. C. FISCHER CO.

HARDWARE

Sheet Metal Work of All Descriptions Our Specialty

Washington Street **Ann Arbor**

Digitized by Google

THE MICHIGAN TECHNIC

VOL. XXVII NUMBER 2 | ANN ARBOR, MICH. OCTOBER, 1914 | PRICE 25c SUB. YEAR, $1.00

TABLE OF CONTENTS

Frontispiece—The New Stadium.

The New Stadium 107

The Development of an Irrigation Project. *F. C. Emerson*, '04E..... 110

The Effect of Heat Treatment on Brass. *Asst. Prof. A. E. White*..... 114

The Graphical Solution of Differential Equations of the First Order. *Prof. T. R. Running* 119

Opportunities in Metallurgical Engineering. *J. H. Herron*..... 127

The New Science Building. *O. W. Hall*, '15E..... 131

One, Two, and Three Hinged Arches. *F. A. Steiger*..... 135

Pere Marquette Appraisal 145

Reclamation of Louisiana's Swamp and Prairie Lands. *A. T. Dusenbury*, '04E.... 146

Self Induction in Transformers. *Prof. G. W. Patterson*..... 149

The Argo Power Plant. *D. A. Smith*..... 151

Editorials 155

Foreword from Assistant Dean.

Departmental Notes 158

Research Work.
New Faculty Members.
Michigan Men in the Press.
Changes in Courses and Faculty.
Improvements in Automobile Laboratory.
On the Campus.

Errata in May Issue 172

Index to Advertisers 161

Digitized by Google

Digitized by Google

VOL. XXVII OCTOBER, 1914 No. 2

THE MICHIGAN TECHNIC

OFFICIAL ORGAN OF THE

ENGINEERING DEPARTMENT

PUBLISHED QUARTERLY

BY THE

ENGINEERING SOCIETY
(INCORPORATED)

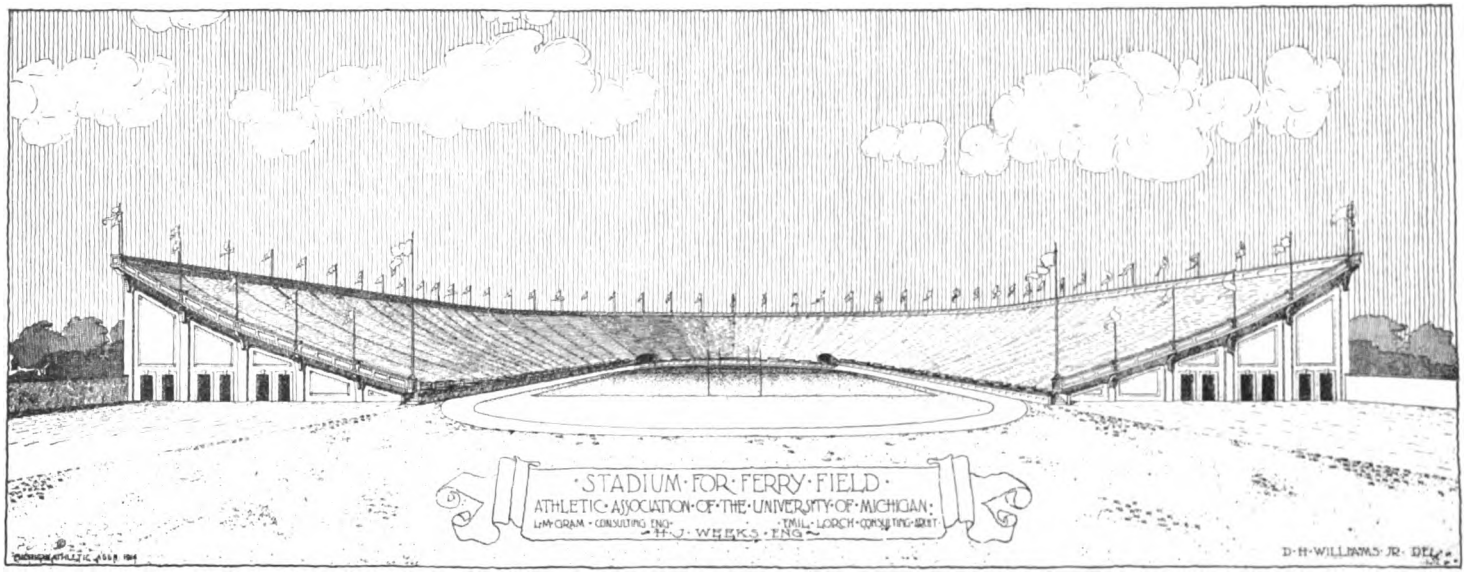
UNIVERSITY OF MICHIGAN

TWO THOUSAND COPIES

PRICE 25 CENTS

SUBSCRIPTION, $1.00 PER YEAR

Digitized by Google


STADIUM FOR FERRY FIELD
ATHLETIC ASSOCIATION OF THE UNIVERSITY OF MICHIGAN
LEMY GRAM · CONSULTING ENG
H. J. WEEKS · ENG
EMIL LORCH · CONSULTING ARCH
D. H. WILLIAMS JR. DEL.

Digitized by Google

THE MICHIGAN TECHNIC

VOLUME XXVII NUMBER 2

PUBLISHED BY THE
UNIVERSITY OF MICHIGAN ENGINEERING SOCIETY

THE NEW STADIUM

The University of Michigan is to have a reinforced concrete Stadium, such as is used by the largest Universities and Colleges in the East. Its construction is being carried out under the supervision of the Athletic Association, and with the assistance of the Engineering Department. The method in which this building is being built and the way in which it is being protected from exterior disturbing conditions make this building extremely interesting from an engineering view point.

The Athletic Association at Michigan is a self-supporting institution depending entirely upon the profits from athletic contests, particularly football, for any monies that it uses in bettering the plant. Notwithstanding this condition the Association has now a plant valued at nearly half a million dollars for the use of the students at the University.

OLD STANDS DEMOLISHED.

Several years ago the new football field was laid out and a new set of wood stands seating 9,000 was built along the North side of it. The stands from the old field were moved to the South side of the field and up to the past three years have been sufficiently large to take care of the crowds at the big games. With the increase in interest in the game, however, it has become necessary to increase the seating capacity. The South stands were costing a large amount in maintenance charges as well as occupying the only available site where an increase in seating capacity could be effected. Director Bartelme and Prof. Whitney of the Board in Control of Athletics last year decided to make a heroic effort to finance the building of a stadium at Michigan. A number of engineers and architects were requested to donate sketches and estimates so that the figures could be presented. The Association has just finished paying for a club-house costing $40,000 and their credit was in very healthy condition as a result. The banks agreed to finance a portion of the stands this year, and in December the full Board in Control selected a building committee and authorized the building of the first unit. In January, at the next meeting of the Board, the plans of H. J. Weeks, ex'07, of Detroit were accepted and he was authorized to place a construction organization on the work and to supervise the entire operation as the Engineer of the Board.

Digitized by Google

The South Stand.

The plans adopted called for the construction of the South leg of the horse shoe shaped stand only. The completed structure has a seating capacity of 47,680 permanent seats. Temporary seats for 5,000 more can be put up at short notice. The unit now under construction is 396 ft. long and 121 ft. 8 inches deep. The front of the stands is 43 ft. from the side lines of the football field and the first row of seats is 4 ft. 6 inches above the field level.

A considerable difference of opinion developed as to the proper width of tread, but a uniform width of 24½ inches was finally adopted. It was soon apparent that if a wider tread were used the only thing to be gained was that people would not have to rise in order to allow others to pass by. This wide tread would be out of the question when the riser was considered. Each successive riser was computed by means of similar triangles, assuming the line of sight of each spectator to the near side line to be 4 inches above the head of the person directly in front. The result gave a bottom riser of about 9 inches and a top riser of about 12½ inches, the intermediate steps ranging between these extreme values. In order to simplify construction it was decided to employ a series of tangents instead of the theoretical curve of risers, the changes in direction of the tangents to be made as closely to the columns as possible. This resulted in a very close approximation to the curve, the clearance of the lines of sight being slightly less than four inches.

There are no entrances or exits built above the ground. Each section of seats occupying 30 ft. in width with a 3 ft. aisle is entered from an inclined passage to the front of the stands. This passage is excavated to a depth of 5 ft. below grade. It is 16 ft. wide and connects with a stairs 8 ft. wide which ends directly in front of the aisle. The stands are 55 rows high and the present unit calls for twelve sections seating 1,100 each. There are twelve main, and two end entrances for this section. The seats will all be 18 inches above the tread next below. This is affected by using a small concrete pedestal varying in height inversely as the height of the riser. To these pedestels a 2″ by 10″ plank is secured. These planks are all the full length of the section, with no joints.

Details of Design.

Upon investigation it was found that the sub-soil was clay, good for 3,000 lbs. The Detroit Building Code allows as high as 8,000 lbs. for the same material. The footing plans were made on that basis, the dead loads only being considered in proportioning the bearing stresses. A footing 6 ft. square and 1 ft. 3 inches thick, reinforced with ½″ Kahn Rib bars, and tied every 12 inches with ¼″ rounds, was used.

The general method of design was that laid down by the American Society of Civil Engineers. The assumed live loads were as follows:

Main Girders and Columns..100 lbs.
Treads and Risers.....125 lbs.
Lateral Pressure ..... 50 lbs.

Risers assumed as semi-Tee Beams and main girders as rectangular beams. Mixture of concrete 1-2-4. Compressive strength 2,000 lbs. in 30 days of Summer weather, as verified by tests of material used in actual construction. Gabriel Trussed bars were used as reinforcement in all risers and Kahn Trussed and Rib bars elsewhere.

Digitized by Google

In order to reduce to a minimum the bending moments in the columns, due to lateral forces or other causes, in a direction parallel to the long axis of the structure, 8 inch diaphragm walls were used; three in each row of columns.

Upon considering the question of evpansion of the concrete, it was learned that the expansion due to moisture was far more dangerous than that due to temperature changes. This was made the subject of a paper by Prof. A. H. White (elsewhere described in this issue) read before the Society of Chemical Engineers. Investigations covering several years show that the expansion of concrete due to moisture may *be sixteen times that due to temperature.* This is a recent discovery, as Prof. White finished his investigations just a few months ago. The stadiums at Harvard, Syracuse, Yale, and other places are causing considerable trouble through cracking of the concrete; due to temperature supposedly, but probably to moisture, on account of their wet, low locations. It is alleged to be a matter of but a few years until they will be condemned unless some radical steps be taken toward obviating the trouble from this cause.

To this end the engineers in charge have arranged to waterproof the exterior of the Michigan Stadium heavily, so as to eliminate all danger from expansion due to moisture. The effect of this water-proofing is being watched with great interest by engineers all over the country, as the results, if successful, will cause marked changes to be made in the present system of concrete work construction. It has been found out that 50% of the failures of reinforced concrete buildings have been due to this recently discovered cause.

Details of Construction.

Bulk cement was used throughout the work, and was stored in a large bin on the premises. Storage capacity in the bins for 2½ cars of each material was provided, and the side track gave storage for 100 cars of sand and gravel. The use of bulk cement reduced the loss on this material to a minimum. Ordinary dump wagons, loaded with a scoop shovel, were used to carry the cement from the cars up the incline to the bins. These bins were lined and covered with iron, to prevent the weather affecting them in any way. The material has required 300,000 ft. of lumber, 5,000 bbls. of cement, 3,750 yds. of gravel, 2,000 yds. of sand, 150 tons of reinforcing steel, and 3,000 yds. of excavation. The total cost of the unit now under construction will be $55,000.

Building Organization.

Engineer H. J. Weeks is in charge of the construction. Prof. L. M. Gram of the Engineering Department, is consulting engineer on the work. Prof. Lorch of the Architectural Department, has charge of that side of the work, while Prof. A. H. White has been advisor on the concrete. Mr. Week's organization handles every branch of the work of construction with the exception of the financial end. Director Bartelme hopes to be able to finance the complete stands shortly so that the work of building the stadium will be continuous.

With the completion of this edifice Michigan will have attained a place in the Football world second to none in the West, and equal to that of any of the Eastern Universities.

Digitized by Google

THE DEVELOPMENT OF AN IRRIGATION PROJECT

F. C. EMERSON, '04 E

WHEN AN engineer first takes charge of an irrigation project he is confronted by three vital tho preliminary questions: Have we the land? Have we the water? Have we a feasible canal line and distribution system? These three questions correspond to the three primary considerations in any irrigation enterprise. There must be a sufficient acreage of good land lying in a position favorable for irrigation, and well located with respect to markets etc.; a sufficient supply of water must be available, either by means of direct flow or storage in reservoirs or both; and the location must allow for a practical system of distributing canals.

It may be in some cases, that the first and second questions can be passed on by the parties back of the enterprise without the services of an engineer, but it is seldom that these parties would let the third question pass without having him make a thorough investigation. Very often the engineer is called upon to investigate thoroughly all three of the matters, before the project can be pronounced feasible. He must, therefore, be prepared to investigate all three when called upon.

The basis of the first question should be apparent to anyone. Just as a merchant must assure himself of a market for his goods before he actually starts his business, an irrigation company must assure itself that there will be a ready market for its reclaimed lands behore it launches upon its project and places its money in it. In most cases, accordingly, an engineer is called to survey and classify all lands within the project. The quantity and quality of the lands must, of course, be considered, but a plentiful quantity of good lands will not alone warrant proceeding with the project. Their position and character with respect to successful irrigation, their location as to markets and transportation lines, their altitude, all have important bearings on the prices they will bring. Some of these matters are more within the professional province of the land-sales expert, it is true, but irrigation companies are often loath to go to the extra expense of hiring such a man. For that reason it is advisable for the irrigation engineer to understand them, and be prepared to give an authoritative opinion on them. In other words, the irrigation engineer must study the business of the land sales expert so far as it applies to localities of the country where reclamation is possible or likely.

In passing on the second question, that of water supply, the engineer must ascertain the annual flow of the stream on which it is proposed to draw. As measurement of stream flow usually requires a long period of time, he should first ascertain if there have been made previous records of flow, and, if there have been obtain them. He will, however, usually wish to establish his own gauging stations immediately upon ar-

Digitized by Google

rival on the project, and for doing this a knowledge of various methods of stream measurement are essential.

If he finds that the direct flow of the stream is not sufficient to furnish all the water needed, investigations of reservoir sites for storage will be called for. A practical reservoir site must have the three qualifications of an ample water supply, a practical dam-site, and a storage basin of sufficient dimensions back of the dam-site. He must give special attention to the foundation for a dam, and to the materials available for construction at or near the site. The materials available for construction, and the accessibility of the site will be the main factors in determining the type of dam to be considered.

The third question, that of a feasible canal or distribution system, resolves itself, for him, into two: What will it cost to construct the system? When constructed, how efficiently will it perform its function of carrying water, and what will be the cost of maintenance? Care must be taken in making these calculations not to carry economy to extremes for serious failures in the system after it is in operation may result in high maintenance costs, and losses in crops to water users He must build with an eye to economy, but not overlook the necessity of safe construction.

The engineer will not usually find it necessary to go into problems of detailed location in this preliminary investigation, but will find rather that the feasibility of the work is determined by a few prominent physical features of the country; such as, certain divides that must be passed through, over or around; certain drainage lines that call for difficult crossings;certain rough stretches of country or formations calling for expensive construction; or combinations of any of these.

The solution of these three main questions, determined by the engineer's preliminary investigations, lead directly to the two items his employers ask for him, the estimated cost of construction on the one hand, and the amount and character of irrigable land, on the other. The value of the preliminary investigation should not be underestimated; the rule in launching an irrigation project should be "look well before you leap." Too often the engineer must fight for sufficient time to make his investigation thorough.

After the project is pronounced feasible, and the order given to go ahead, the engineer enters upon a new series of labors. These may be placed under the two heads of location and construction, and operation and maintenance. Operation would not come under the work of the engineer except for its close connection with maintenance, which often calls for especial skill on his part; and, moreover, operation is always the final test of location and construction. Thus it is important to the engineer to understand fully the operation of a system In fact, it is only after one has seen a head of water creeping through a long system of canals and ditches, apparently in search of a weak, point and had occasion to repair failures in this system, that he can fully realise what special construction and location is necessary to assure the ultimate working success of a sys-

Digitized by Google

tem. Many details that would not otherwise be realised or impressed upon him come through experience in operation and maintenance.

The preliminary surveys of the project will probably have closely decided the lines of location of the system as a whole. After it has been decided to construct, the first thing in order is usually a detailed survey of the system. The cross-section or construction surveys and the actual construction work follow. In this work of location and construction the engineer must aim to have low the costs, not only of initial construction, but of probable maintenance after the system is in operation.

In connection with location and construction the need for a knowledge of mineralogy and geology is very important. And it is a need that is often not appreciated. An engineer of the writer's knowledge, for instance, a man of broad experience in railroad construction, when asked to classify a certain piece of material which careful analysis showed to contain about 7 per cent lime, called it limestone. Asked what limestone consisted of, he did not know, except that it contained lime; but what percentage of lime was necessary in a rock before it could be classed as limestone he could not say. He could only tell what it was when he saw it, without knowing just why it was limestone; "he was only an engineer, not a geologist."

The effect on a jury of this kind of expression can well be imagined, when it was easily shown by the opposition that the rock in question contained principally alumina and silica, and was thus a shale, far removed from limestone. It was very important, in this case, whether the material was the one or the other, and parallel cases are arising constantly.

This case impressed upon the writer, also, the importance of clarity and definiteness in classification specifications for construction. Different prices are paid for different materials, because the costs of excavating vary. In the litigation above referred to, the third class in the specifications was described by the one word "shale." Anyone familiar with shale will know that it is found in many different forms and conditions, so that it may be in any one of the four classes usually named in specifications, and often the four classes of shale will occur in the same cross-section. Thoroughly decomposed shale is an earth, or first class material; under the covering of earth it will be found in a more compact formation, excavated at about the same cost as gravel or hardpan; under this will occur a solidified formation, excavated about as "loose-rock" of the third class; and finally a formation is reached which works like "solid rock," and should be placed in the fourth class. In describing "shale" definitely as only a third class material, it is readily apparent that in drawing up specifications the consideration was lost sight of that different classes should be so described as to conform to the expense of excavation. The result of such looseness is usually trouble for all parties, constructing company, contractor and engineer.

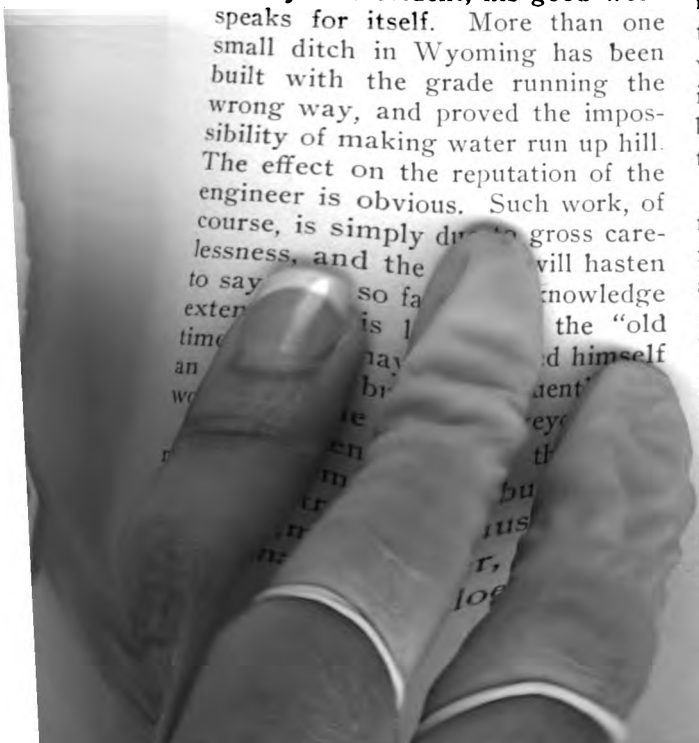
Thus exactness of specifications—and this exactness requires special

Digitized by Google

knowledge on the part of the engineer cannot be overemphasized. In connection with matters of litigation, where the importance of it so often is made manifest, it may be well to mention also, the importance to the engineer of some knowledge of irrigation and contract law. This is another thing that he must possess.

Canal location and construction demands of the engineer a thorough knowledge of the flow of water in open channels, pipes, etc. He finds plenty of use for his study in design and S. and R. in considering wastegates, siphons, flumes, tunnels, weirs, drops, division boxes, turnouts and others that occur in irrigation construction work.

The final test of an engineer's work on an irrigation project is, as previously suggested, its operation after completion. Truly his work is a monument to him. His errors are ever present, and cannot be buried, while, on the other hand, although usually less evident, his good work speaks for itself. More than one small ditch in Wyoming has been built with the grade running the wrong way, and proved the impossibility of making water run up hill. The effect on the reputation of the engineer is obvious. Such work, of course, is simply due to gross carelessness, and the [illegible] will hasten to say [illegible] so far [illegible] knowledge [illegible] the "old [illegible] himself [illegible]



terialize. A canal system will usually display several freaks after water is turned in; it may fail at points where trouble was least expected, or may prove strong at other points where trouble would naturally be looked for. Definite rules cannot be laid down for all cases. While in some cases a seepage or well defined leakage, a sloughing or settlement of embankment may demand immediate action, in still other cases the leakage may stop naturally, or the sloughing may arrest itself without any action being taken at all; all depends on different conditions existing in the two cases. In maintenance the engineer is afforded rare chance to use his judgment in the securing of safety on one hand, and economical administration on the other.

The work of operation, although it requires the exercise of much judgment in the administration of water through the system, is mostly routine. A knowledge of the measurement of water is, of course, essential. The system should be so provided with wastegates throughout its length that the flow of water can be well regulated from headgate to terminus.

The foregoing is a brief and hasty recital of some things in an engineer's part in the development of an irrigation project as the writer sees it after some experience. I have endeavored to point out the important things the engineer is called upon to do, and to call attention to certain branches of information and knowledge, many not of a technically engineering character at all, which an engineer can well use, and often must use, in practice.

Digitized by Google

THE EFFECT OF HEAT TREATMENT ON BRASS

ASST. PROF. A. E. WHITE

In the manufacture of many brass products it is the custom to do considerable of the shaping at the atmospheric temperature. Such a procedure greatly distorts the metallic crystals and, if carried too far, causes the lines of cleavage to separate to such an extent that the object splits. In order to prevent such an occurrence the product, after it has undergone some reduction, the amount of reduction depending upon a number of conditions and varying in quantity from a mere trace to 33 ⅓ per cent, is annealed. This is performed by heating the metal, even to the very center, to some temperature between 600° F. and 1200° F. The method of cooling from this temperature with compositions containing more than 63 per cent of copper and less than 37 per cent of zinc is immaterial.

Condenser tubes are brass products which, in their process of manufacture, undergo a treatment similar to that spoken of above. Tubes for this use contain from 60 per cent to 90 per cent of copper and from 40 per cent to 10 per cent of zinc. There are also some tubes made from an Admiralty formula consisting of 70 per cent of copper, 29 per cent of zinc, and 1 per cent of tin, and in addition there are some tubes of special composition that are now undergoing a more or less severe service test. The most common process employed in the manufacture of tubes of this kind is to pour the molten alloy from crucibles of not over 200 pounds capacity into billets and to then cold work and cold draw these billets, with proper annealings interspersed, until a finished tube results.

For the purpose of determining the influence of heat treatment on the structures of a condenser tube the writer took a tube of the following composition and, after subjecting portions of it to a number of different heat treatments, examined the different sections under the microscope.

Chemical Composition of Condenser Tube

Copper	66.94%
Zinc	32.95%
Lead	Trace
Iron	.12%
Antimony	None
Arsenic	Less than .02%
Bismuth	Less than .02%

Ten samples were examined. These included one "As Received"; another, heated to 100° C. and air cooled; a third, heated to 200° C. and air cooled; a fourth, heated to 300° C. and air cooled; a fifth, heated to 400° C. and air cooled; a sixth, heated to 500° C., and air cooled; a seventh, heated to 600° C. and air cooled;; an eighth, heated to 700° C. and air cooled; a ninth, heated to 800° C. and air cooled; and the last or tenth, heated to 900° C. and air cooled. The structures of these respective tubes are given in the latter portion of this article.

On heat treating these tubes it was considered sufficient to only keep them at the required temperature for about fifteen minutes, for the cross section of the tubes was so small that longer heating was unnecessary to get the given temperature through to the core. The object was to determine the temperature necessary to remove the grain distortion produced by the cold

Digitized by Google

working but which would not be high enough to cause coarse crystallization. In this particular case it was found that 400° C. was the correct annealing temperature. To be sure, a lower temperature would have served the same purpose if the specimens had been held for a longer period of time. Hudson and Benough, for example, found that a Muntz metal, which is composed of 60 per cent of copper and 40 per cent of zinc, gave maximum ductility when heated for seven hours at temperatures between 560° C. and 690° C. The same metal when annealed but half an hour required a temperature of 750° C. to bring the maximum ductility. The significance of this, metallographically, is that the same result—the removal of the strain caused by cold working—can be attained by holding the metal for a long time at a low temperature as by holding it a shorter time at a higher temperature.

On examining the photomicrographs, we find that the one marked "As Received" shows a rather coarse grain with many indications of strain. Heating to 100° C., 200° C., and 300° C. has produced no change. The 400° C. heat treated sample, however, shows a breaking down of the preceding type of somewhat distorted crystalization, which is more marked in the 500° C. heat treated specimen. The 600° C., 700° C., and 800° C. specimens give excellent proof that the size of crystals increases as temperature increases above temperature at which recrystalization first begins to take place. The 900° C. sample shows the characteristic appearance of a burned tube.

All of these structures were brought out with a special etching reagent consisting of five cubic centimeters of hydrogen peroxide mixed with ten cubic centimeters of water. The etching took about twenty seconds. The photomicrographs are all magnified 75 times. The alloy has but one component, namely, alpha (a) crystals, because the composition is such that there is only present an alpha (a) solid solution.

It is necessary that care be taken in the temperature of annealing of brass condenser tubes. If the temperature is too high, or if the tube is maintained for too long a time at a temperature which would prove satisfactory for a brief exposure to the annealing conditions, the crystals of the tube will become coarsened and permit corrosion to take place more readily. Furthermore, if the strains produced by the last cold drawing are not completely removed the tube will tend to split. Thus a fine grained, strain free tube should be the goal. This investigation was prompted by the repeated splitting of commercial condenser tubes and since careful annealing has been insisted upon there have been less failures.

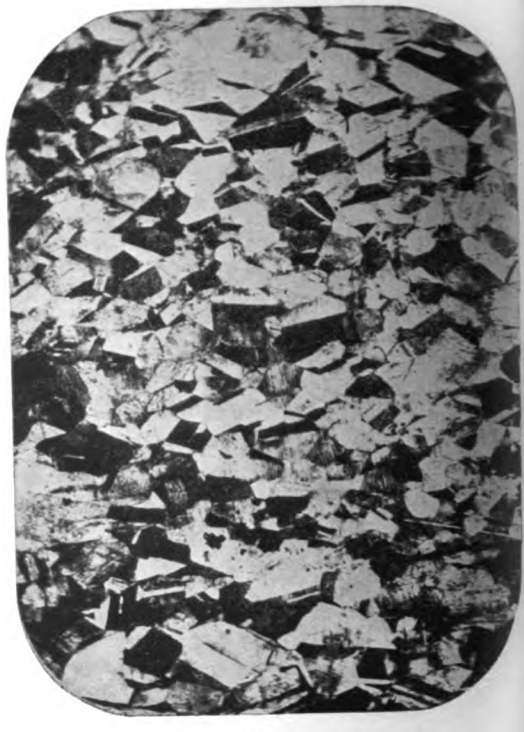
List of Photographs.

No.	*Treatment.*	*Surface.*	*Magnification*
1.	As received	Outside	75
2.	100° C. air cooled	"	"
3.	200° C. " "	"	"
4.	300° C. " "	"	"
5.	400° C. " "	"	"
6.	500° C. " "	"	"
7.	600° C. " "	"	"
8.	700° C. " "	"	"
9.	800° C. " "	"	"
10.	900° C. " "	"	"

Digitized by Google

No. 1

No. 2



No. 3

Digitized by Google

No. 4

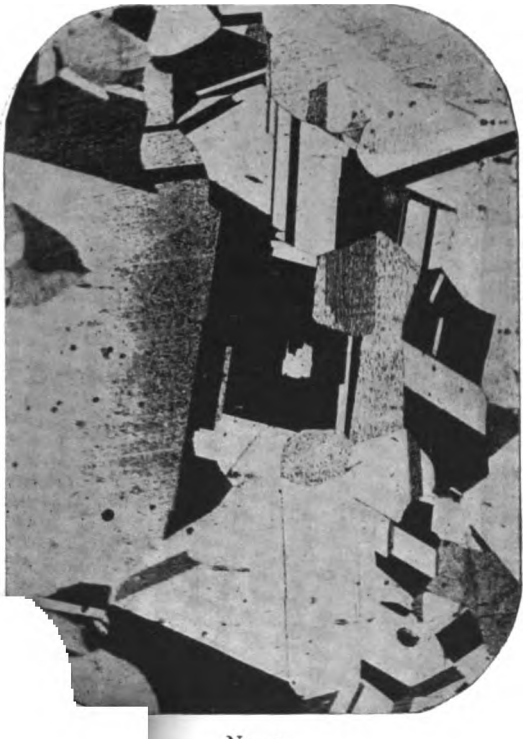
No. 5

No. 6

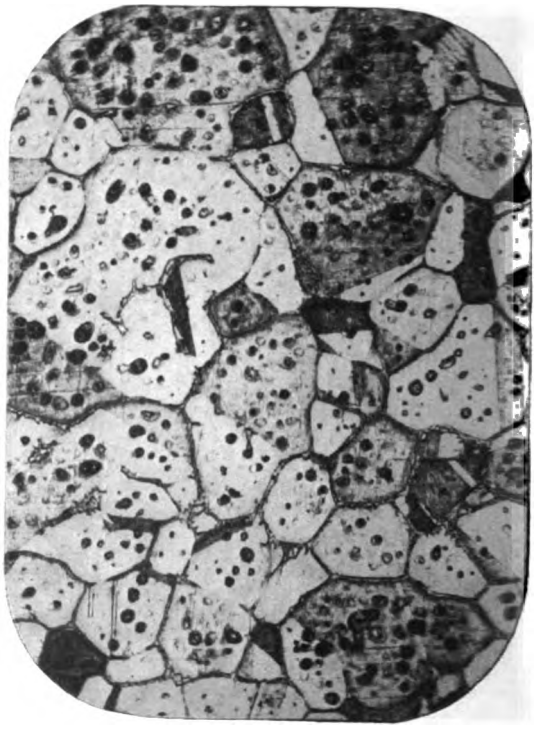
Digitized by Google

No. 7

No. 8



No. 9



No. 10

Digitized by Google

THE GRAPHICAL SOLUTION OF DIFFERENTIAL EQUATIONS OF THE FIRST ORDER

PROF. T. R. RUNNING

Owing to difficulty in setting up the equations in this article, fractional exponents are represented by symbols as follows: 3-2 for 3/2; 5-6 for 5/6.—EDITOR.

If the differential equations which occur in problems of engineering were always of the type we became familiar with in our text-books there would be no need of graphical solutions. Unfortunately, however, many of the equations which arise from conditions involved in problems are of a type which cannot be solved by ordinary methods. We would not think of solving a differential equation graphically if its analytic solution could be readily obtained. But when the solution cannot be obtained or is obtained with difficulty we naturally welcome any approximate solution provided the errors involved in such a solution fall well within the limits of allowable errors.

It is the purpose of this paper to explain a graphical method applicable to any differential equation of the first order, and which requires no more knowledge of the calculus than the geometric meaning of derivation and an understanding of the relation of the integral curve to its derived curve.

The following problem, involving differential equations, will serve as an illustration and its solution will be carried out later. It was found by a series of observations, over the particular region involved, that the limits of water discharged into a reservoir basin during a flood could be fairly well represented by the expression

$$S = 1800\, t,$$

until a maximum was reached, after which the water discharged into the basin could be represented by

$$S = 1740 - 240\, t,$$

where s represents acre-feet per day and t time in days. The spill-way was 40 ft. long and from the formula which expresses the quantity of water flowing over weirs it is easily seen that the water discharged over it is represented by $132\, h^{3-2}$ acre-feet per day, where h stands for the depth of water in feet. By the application of the method of least squares to the data obtained by a careful survey of the region it was found that the water surface of the reservoir could be represented to a close approximation by

$$A = h^{2-3} + 1000 \text{ acres.}$$

where A stands for the number of acres and h, as before, represents the depth of water in feet. The problem is to find values of h at frequent intervals up to a maximum together with the corresponding values of t.

Digitized by Google

The differential equation expressing the fluctuation of water level from the time the flood begins to the time of maximum in flow of water is

$$\frac{dh}{dt} = \frac{1800\,t - 132\,h^{2.2}}{11\,h^{4.5} + 1000}$$

From the time of maximum in flow to the time when the flood ceases the fluctuation of water level is expressed by

$$\frac{dy}{dx} = \frac{1740 - 240\,t - 132\,h^{2.2}}{11\,h^{4.5} + 1000}$$

The method of obtaining these equations will be explained when the solution of the problem is taken up. For the present it is sufficient to note that these equations do not yield to the ordinary methods of treatment.

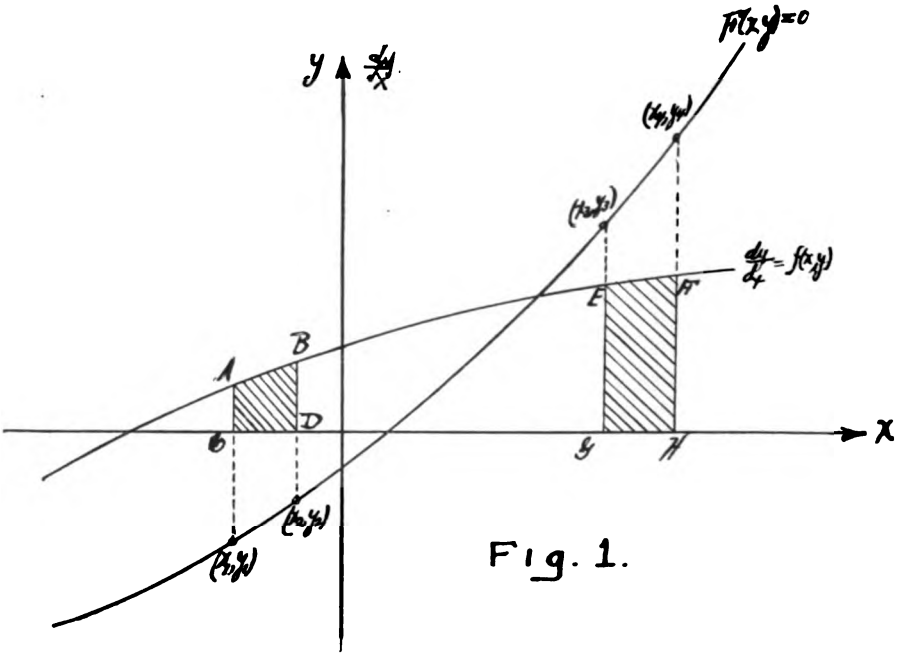


Fig. 1.

The graphical solution of the differential equation of the first order will be found, it is thought, quite easily carried out and the approximation to the result very close.

Figure 1 represents the relation of a given curve to its derived curve. The area under the derived curve

$$\frac{dy}{dx} = f(x, y)$$

included between any two ordinates is equal to the difference between the corresponding ordinates on the integral curve; that is to say,

$$\text{Area } A\,B\,C\,D = y_2 - y_1$$

The area expressed by the left hand member of the equation is positive,

Digitized by Google

y_2 and y_1 negative, but y_1 being numerically the larger makes the right hand member positive. Also

$$\text{Area } EFGH = y_4 - y_3$$

Expressed as integrals

$$\text{Area } ABCD = \int_{x_1}^{x_2} f(xy)\,dx = y_2 - y_1 \text{ and}$$

$$\text{Area } EFGH = \int_{x_3}^{x_4} f(xy)\,dx = y_4 - y_3.$$

It should be kept in mind that the slope of the integral curve, $F(xy) = 0$, any point (x_n, y_n) is equal numerically to the corresponding ordinate on the derived curve. From figure 1 it is seen that the slopes of the integral curve

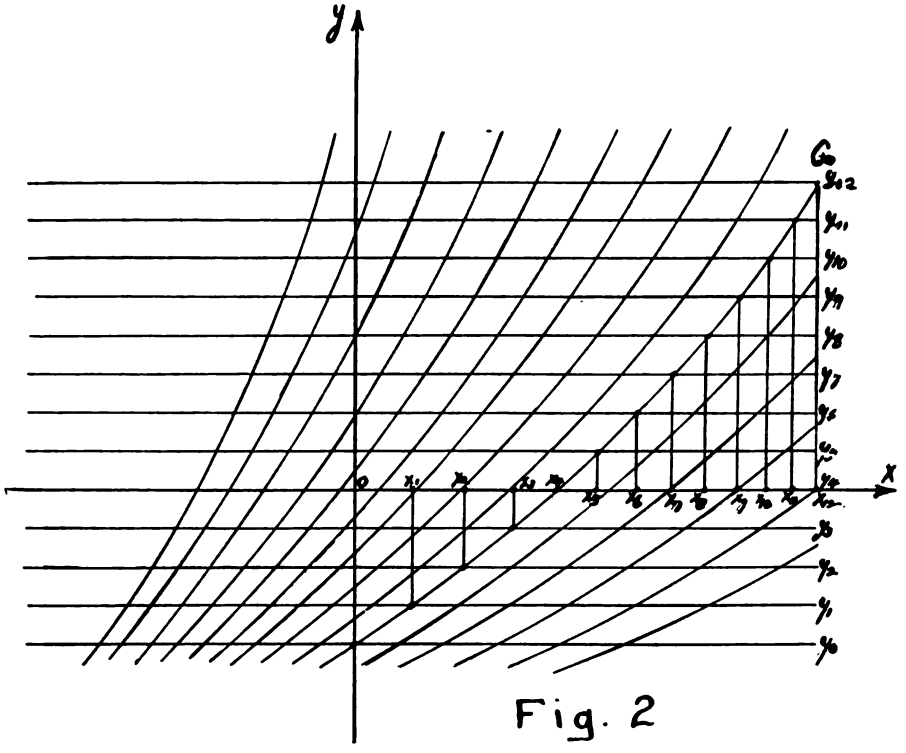


Fig. 2

at the points (x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4) are AC, BD, EG, and FH respectively. These properties of the integral and derived curves are made use of in the graphical solution of differential equations.

Since $F(x, y)$ is the integral of $f(x, y)dx$ it contains an arbitrary constant. For every value assigned to this constant we will have a particular curve. In figure 1 a value has been assigned to the constant. Clearly $F(x, y) = 0$ will then represent an infinite number of curves. Figure 2 shows how these curves may be related to one another. We will draw lines parallel to the x — *axis*, represented on the figure by y_0, y_1, y_2, y_3, etc., and

Digitized by Google

imagine that the curves are drawn infinitely near together. Fixing our attention upon the points where the line y_1, say, intersects the curves, we see that the slope of any particular curve where it is intersected by the line y_1 is

$$\frac{dy}{dx} = f(x, y_1),$$

x being the abscissa of the point of intersection and y_1 the ordinate. If we now compute the slope of each curve where it intersects the line y_1 and plot the value of this slope as ordinate to the corresponding value of x as

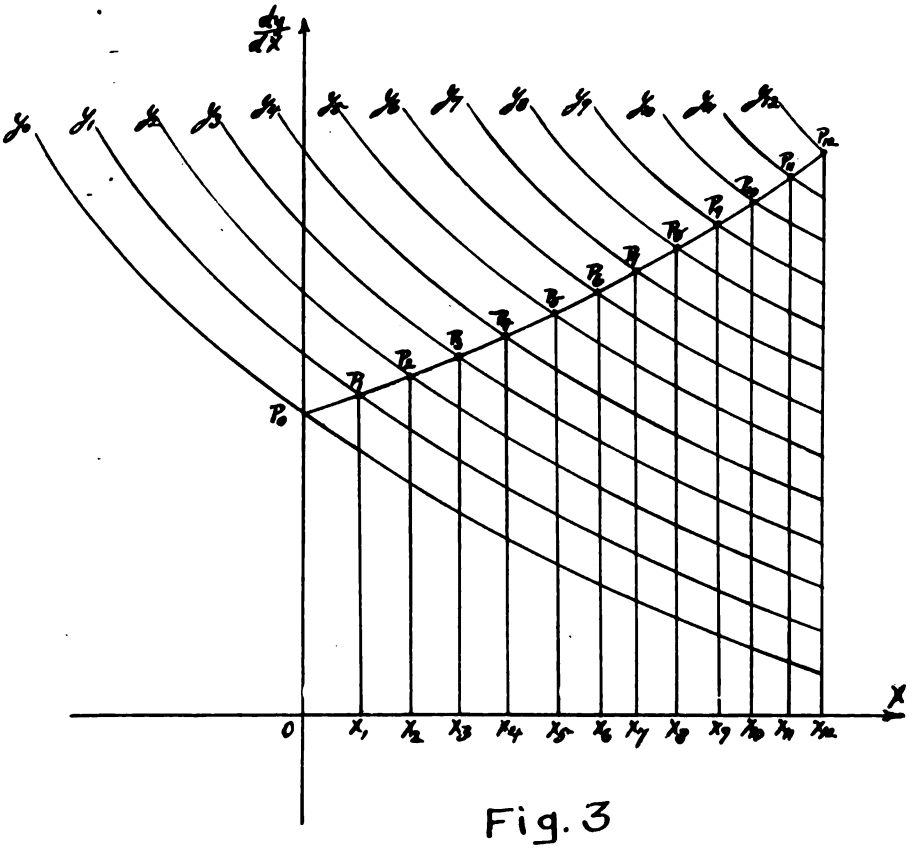


Fig. 3

abscissa we shall have a new curve which will represent the slopes of the curves along the line y_1. This curve is drawn in figure 3 and designated by y_1. Each curve in figure 3 is obtained in the manner just described and designated by y with the same subscript as the corresponding straight line in figure 2. The equations of these curves, which we will call auxiliary curves, are obtained by substituting different values of y in the equation

$$\frac{dy}{dx} = f(x, y).$$

If we now impose the condition that the integral curve shall pass through the point (o, y_0) it is evident from figure 3 that its slope at this point is oP_0.

Digitized by Google

Drawing a curve, which for an approximation may be a straight line, from the point P_0 to a point P_1 on the curve y_1 such that the area under it is equal to $y_1 - y_0$, and keeping in mind the properties of the curves discussed at the outset, we see that (x_1, y_1) will be a point on the integral curve. Drawing a line from P_1 to a point P_2 on the curve y_2 such that the area under it is $y_2 - y_1$ another point (x_2, y_2) on the integral curve is obtained. Proceeding in this way any number of points on the integral curve can be obtained. It is to be observed that in figure 3, P_0, P_1, P_2, P_3, etc., are points on the derived curve, and that the coordinates of points on the integral curve are read from this figure and located in figure 2. To illustrate, P_6 is a point on the derived curve. Its obscissa x_6, is equal to the abscissa of the corresponding point on the integral curve, the ordinate of the point on the integral curve is the y designating the curve passing through h P_6. The curve designated C_0 in figure 2 is the integral curve whose derived curve is determined by the points P_0, P_1, P_2, P_3, etc., in figure 3.

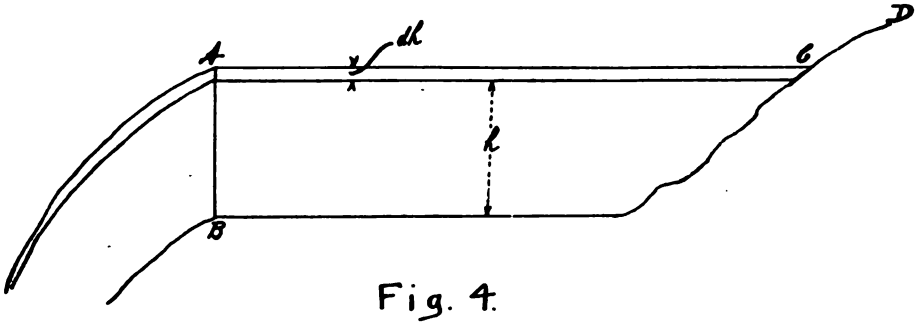


Fig. 4.

We are now ready to take up the solution of the problem stated at the beginning. Figure 4 is a rough sketch of a vertical section of the reservoir during the flood. AB represents the spill-way, BC the bottom of the reservoir and AC the water surface. The water flowing down the slope CD is discharged into the reservoir at the point C, or it may be at a number of points; h represents the depth of the water assuming that the bottom of the reservoir is level and even with the crest of the spill-way. It is clear that if the rate of inflow at C is greater than the rate of outflow at AB h is increasing, and if the rate of inflow is less than the rate of outflow h is decreasing. There must necessarily be a time when h is a maximum.

Figure 5 represents roughly the flood limits of inflow. The ordinates on the line $S = 1800\,t$ represent the rate of inflow in acre-feet per day up to a maximum. This maximum rate of inflow occurs earlier than the maximum depth of water in the reservoir. The ordinates on the line

$$S = 1740 - 240\,t$$

represent the rate of inflow after the crest of the flood has passed. It is clear that the greatest rate of inflow will occur when $t = .853$ day. By referring to figure 4 it is seen that the rate of inflow minus the rate of out-

Digitized by Google

flow must be equal to the area of water surface multiplied by the rate of change of h or

$$I - O = S\frac{dh}{dt}$$

where I stands for rate of inflow, O for rate of outflow and S for water surface. From the differential equation

$$\frac{dh}{dt} = \frac{I - O}{S}$$

is obtained, by substituting for I, O. and S their values given in the problem, the differential equations which express the fluctuation of water level:

(1) $$\frac{dh}{dt} = \frac{1800\,t - 132\,h^{\frac{3}{2}}}{11\,h^{\frac{4}{3}} + 1000}$$

(2) $$\frac{dh}{dt} = \frac{1746 - 246\,t - 132\,h^{\frac{3}{2}}}{11\,h^{\frac{4}{3}} + 1000}$$

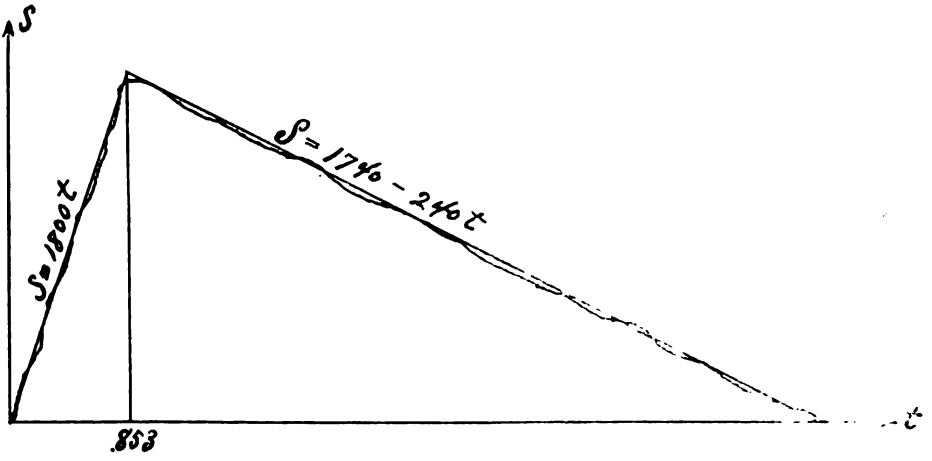


Fig. 5.

Equation (1) must be satisfied from $t = 0$ to $t = .853$, equation (2) from $t = .853$ to $t = 7.25$. As will be seen the maximum value of h occurs long before t reaches the value 7.25.

The solution of the problem is given in figure 6. Since $h = 0$ where $t = 0$ the first auxiliary equation will be obtained by substituting this value for h in (1).

In the accompanying table are given the auxiliary equations with the corresponding values of h and t.

The value .623 for h is obtained by so selecting it that the area under the derived curve (here the dotted line) from $t = 0$ to $t = .853$ is equal to h. The auxiliary curves are straight lines and are designated by the selected values of h. The value of h will be a maximum when $dh/dt = 0$ which occurs 4.5 days after the flood began to discharge water into the reservoir.

Digitized by Google

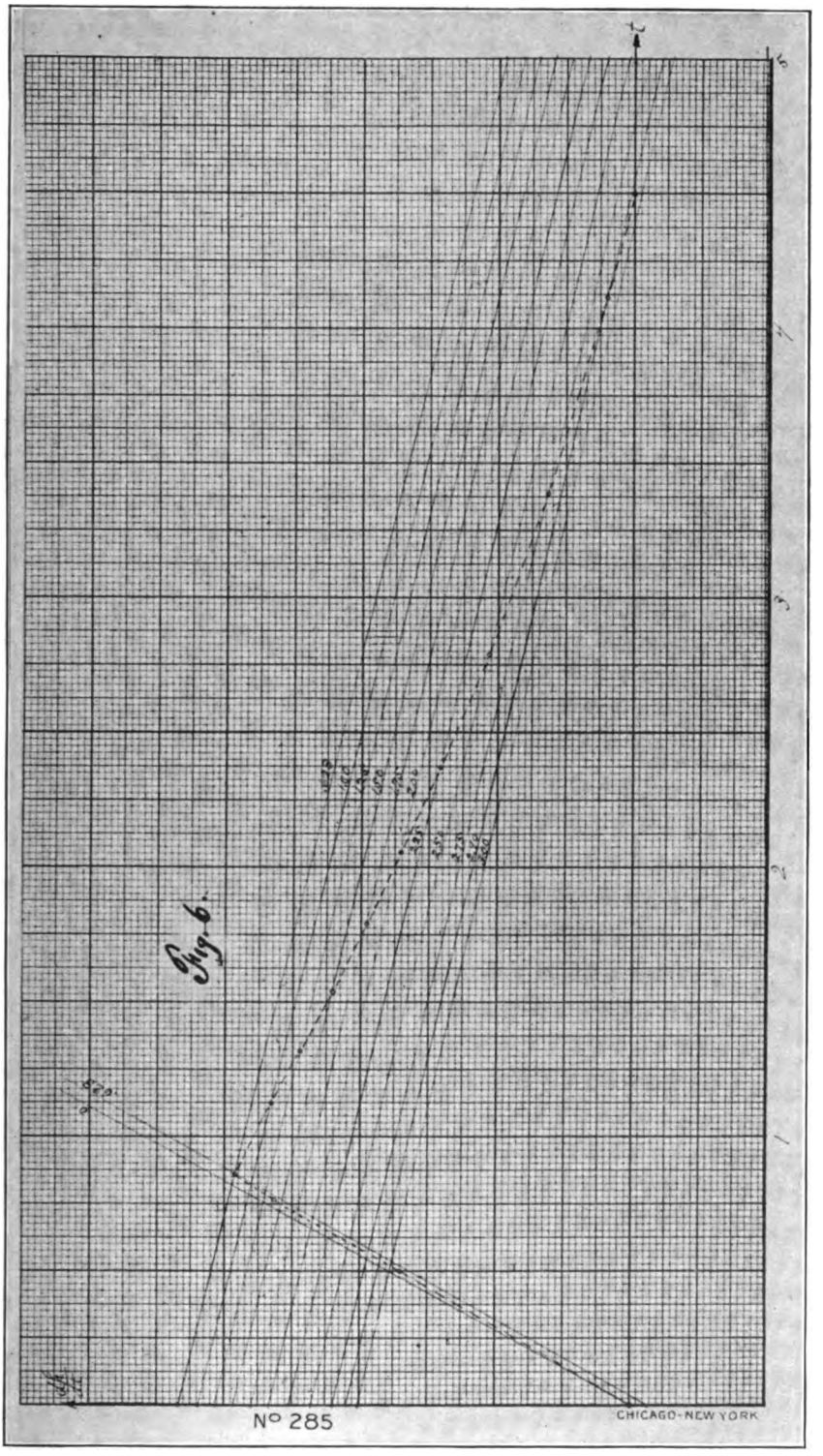


Fig. 6

Digitized by Google

From (1)			
$\frac{dh}{dt}$ =		h	t
"	1.8 t	0	0
"	1.791 t − 0.046	0.5	0.212
"	1.789 t − 0.065	0.623	0.853
"	From (2)		
"	1.665 − 0.2385 t	0.623	0.853
"	1.591 − 0.2374 t	1.00	1.125
"	1.534 − 0.2366 t	1.25	1.320
"	1.471 − 0.2358 t	1.50	1.54
"	1.402 − 0.2350 t	1.75	1.78
"	1.333 − 0.2341 t	2.00	2.05
"	1.258 − 0.2332 t	2.25	2.37
"	1.179 − 0.2323 t	2.50	2.78
"	1.097 − 0.2314 t	2.75	3.38
"	1.047 − 0.2309 t	2.90	4.11
"	1.040 − 0.2308 t	2.92	4.50
"	1.031 − 0.2307 t	2.95	
"	1.011 − 0.2305 t	3.00	

Its value is 2.92 ft. More points on the integral curve can readily be obtained. Beyond the point where h is a maximum dh/dt is of course negative.

It may be well to point out again that the difference between any two successive values of h is equal to the area under the derived curve between the two corresponding values of t.

In finding values of h and t beyond those given in the table it must be remembered that the area below the t axis is to be taken negative and the derived curve will therefore cross the lines in the reverse order.

Digitized by Google

OPPORTUNITIES IN METALLURGICAL ENGINEERING

J. H. HERRON, '09 E

To every young man who thinks he has made his decision to take a course in engineering, this question must invariably arise; if not before entering college, at least before the beginning of his second or third year.

Perhaps, before considering this question in detail, it may be wise to see whether sufficient thought has been given to the subject in general, i.e., "am I sure that I wish to be an engineer, or am I qualified by natural desires and tendencies to fit into the life and give myself up to the activities of the engineer?"

There seems to be somewhat of a misapprehension regarding the profession of engineering, and this should be corrected as far as possible. This condition of mind may be accounted for by the tendency of present day novelists to make of the engineer a hero of romance. While the true engineer loves his profession, he realizes that it is not, more than other professions, a path of roses.

The engineer in addition to a natural fondness for his work, must be honest, unselfish and patient. There are times when temptations will assail him in subtle forms and he must be honest and strong to resist. Much of the work of the engineer is done with little personal profit. He frequently receives the credit for what he has accomplished, but even this, at times, is denied him and such credit goes to the undeserving, therefore he must give up these stimulating returns and content himself with his own knowledge of a work well done. The engineer who was the real inventor of the so-called Corliss Valve Gear, which revolutionized steam engineering, received practically no profit from his invention, and it was not until later years that he was recognized as the inventor. Today, few outside the engineering profession have ever heard his name. The engineer is primarily a director of men and as such he must frequently become the buffer between two opposing elements. This will at times try his soul. These things are all inseparable from any branch of engineering and must be well considered before the subject is further entered into.

The exceeding rapid and extended growth of accomplishment in the field of engineering requires that the student shall have a thorough preparation in the branch of engineering that he shall select to study, and ultimately must expect to closely specialize in it. It has been recognized for some time past that in all large work it is better to have the co-operation of a number of specialized engineers than that all shall be in the hands of one engineer. Co-operation is, without doubt, the watchword of the engineering future. One eminent engineer has said that much better results would be gotten by several special engineers of ordinary ability than by one general engineer of extraordinary ability.

Digitized by Google

In all branches of engineering, the student must have some natural aptitude towards the particular branch which he desires to study. It is not only necessary to say, "I shall be this," for it to come to pass. Every man, no matter in what branch of engineering engaged, must have the power to dream, and to bring his dream to pass in the accomplishment of something for the benefit of his fellow men.

In this age of iron and steel, and other metals, there is no more important place in the economy of engineering than that filled by the metallurgical engineer. It is upon him that the responsibility rests to take the ore that nature provides and to fashion it into forms available to his brother engineers for use in the fabrication of the many machines, structures, etc., upon which all depend. Owing to the tremendous strides made in the manufacture, treatment and use of metals, notably alloy steels, in recent years, it is felt that we are entering upon a new era in metallurgy, and in the future, wonderful developments in engineering endeavor along these lines may be looked for.

The metallurgical engineer is more a combination of the scientist and engineer than is usually found in other branches of engineering. He must devote much time to research work, which belongs to the realm of science, and as an engineer must be able to take results of his research work and make it commercially practical.

Metallurgical engineering properly falls into two divisions.

First: That which appertains to the manufacture of the different metals from their ores into ingot or other forms for ordinary use.

Second: That which governs the selection of different metals and the subsequent treatment to give them for certain scientific purposes.

In the first instance the metallurgical engineer must watch the manufacture of material from the ore to the commercial product. Upon his skill and honesty will depend much of the success of the design and fabrication of all classes of machinery, bridges, buildings, etc. Inferior materials delivered to the fabricator may result in subsequent failures entailing loss of life and property.

The second division of this subject is one which is comparatively new, and will in consequence be treated at greater length.

Until a few years ago, the selection of iron, steel or other metals, for any particular requirement was left to the metallurgical engineer who had made the material. As manufacturing needs developed and it was found that the metallurgical engineer, in such capacity, was not the user to any extent of the material that he manufactured, and therefore did not have the fullest conception of the needs of the user, a new branch of metallurgical engineering, coming under the latter heading was found necessary. This branch of the subject has for its purpose the proper selection of material and its subsequent preparation for certain engineering operations, so that now, as a rule, great care is exercised, not only in the selection of material, but in its thermal treatment. Such treatment has at times as much as doubled the physical value of the material for service.

Digitized by Google

The metallurgical engineer is, perhaps, primarily a scientist, that is, he must have such a knowledge and understanding of chemistry and physics that he can think in them. Unless this is possible he would be unable to meet the problems constantly arising and which he must frequently solve without the aid of existing literature on the subject. The research necessary requires that he shall have sufficient knowledge to be able to understand the phenomena resulting from his experimental work. In order to properly observe and record experimental phenomena the metallurgical engineer should have more than the ordinary mathematical mind and training, since his work requires the degree of exactness only possible to such a mind. As an engineer he must be able to take the results of his experimental work and make it a commercial success in such place or connection where it seems desirable.

It was the work of Mr. Fred W. Taylor, the well known efficiency engineer, and Mr. Maunsel White, metallurgical engineer, along experimental lines that resulted in the discovery of the so-called high speed tool steel. The introduction of high speed tool steel in turn has necessitated the re-design of nearly all metal working machinery. There are now coming on the market tool alloys, which their discoverers claim, are as far in advance of high speed tool steel, as high speed tool steel was in advance of ordinary tool steel.

Perhaps the greatest development along this particular branch of metallurgical engineering has been caused by the need of the automobile industry. Here was a problem not met with before where a high degree of strength was necessary with light weight. There was the cost of up-keep of the automobile, which included, tires, fuel, etc., and the requirements of speed, all of which contributed to the necessity of reducing the weight to a minimum. The metallurgical engineer made this possible by the development and the introduction of alloy steels together with the necessary greatest possible strength. As a result we now hear of comparatively few failures, and the automobile salesman impresses the prospective purchaser with his familiarity with nickel, vanadium, and chrome nickel steels and their heat treatment.

The duties of a metallurgical engineer are: to study the physical requirements of a particular part of a machine or structure or the amount and kind of load to which it is subjected; to select the material best suited to the part and service in question; and to decide upon the heat treatment necessary to produce the desired physical properties. This, of course, will necessitate the chemical examination of the material to determine whether it is of the desired composition, and the inspection and testing of the material physically to determine whether it possesses the desired physical properties. All of this presupposes:

a. A knowledge of the service to which a material is to be subjected. the extent and kind or character of stress applied to the part in question.

b. A knowledge of the action of metals under different kind of stress.

c. A sufficient knowledge of

Digitized by Google

chemistry to be able to determine whether the material is of the desired composition.

d. A knowledge of the effects of thermal treatment upon the physical properties of the material.

e. A knowledge of physical testing and the necessary experience to draw proper conclusions from such tests.

The microscope has opened an entirely new and very interesting field in metallurgical engineering. This particular division of the work is designated by the term "metallography,"and the engineer engaged in such work is known as a metallographist. Metallography has enabled the engineer to determine many things which have heretofore been seemingly beyond solution. By such means it is possible to ascertain the approximate mechanical and thermal treatment to which any material has been next previously subjected, thereby enabling the metallographist to learn what mistreatment, if any, has been given a material either in manufacturing, subsequent melting or preparation for use. Even at times the cause of a failure in service may be determined and proper measures taken to prevent a repetition of the same fault. Such work has been of incalculable benefit to the whole manufacturing industry. With the opportunity and prospect for its future developments, much is to be expected from its use.

Practical work in metallography is only possible after considerable training on the part of the engineer

If, after considering all reasons for and against, the student has decided to become an engineer, he must then with great care select the particular branch for which he feels that he can qualify. As human knowledge on this subject increases there becomes less room for the indifferent one, and only to those who are willing to give of their strength without permitting the thought of material gain to occupy too much of their horizon, will success come.

As the future will be one of cooperation the engineer must be willing and anxious to work with his fellow engineers, recognizing in them their respective abilities.

Since the science of metallurgy is but in its infancy, metallurgical engineering opens to the student a field possessing perhaps, a more diversified interest than any other branch of engineering. Much of the satisfactory performance of all machines, steel structure, etc., will depend upon his knowledge and skill. It in turn requires more the training of a scientist than is usual.

The world of tomorrow may be under the direction of the engineer. With the increasing need of the technically trained man at the head of large manufacturing interests, therew will be development along new and diversified lines, and new classes of engineers will result. There may eventually be a large class of business men educated as engineers, in order that they may the more readily meet the problems confronting them as executives. More and better iron and steel will be necessary and without doubt metallurgical engineers will become the executive heads of the large iron and steel plants. With engineers at the helm of our large industries there will be less danger of erring, due to ignorance, and the world will be a safer place in which to live.

Digitized by Google

THE NEW SCIENCE BUILDING

O. W. HALL, '15 E

At the last session of the Legislature, $375,000 was appropriated for the construction of the new Natural Science Building for the University of Michigan. This will give vastly improved facilities for instruction and research in the branches of Botany, Forestry, Geology, Mineralogy, Zoology and Psychology—all of which will be housed in the new structure. Albert Kahn, of Detroit, the designer of the Hill Auditorium, has attempted to make the new building harmonize with the others on the campus, although the peculiar requirements of the new building necessitated some radical changes from the present scheme.

East Side of Building

General Description.

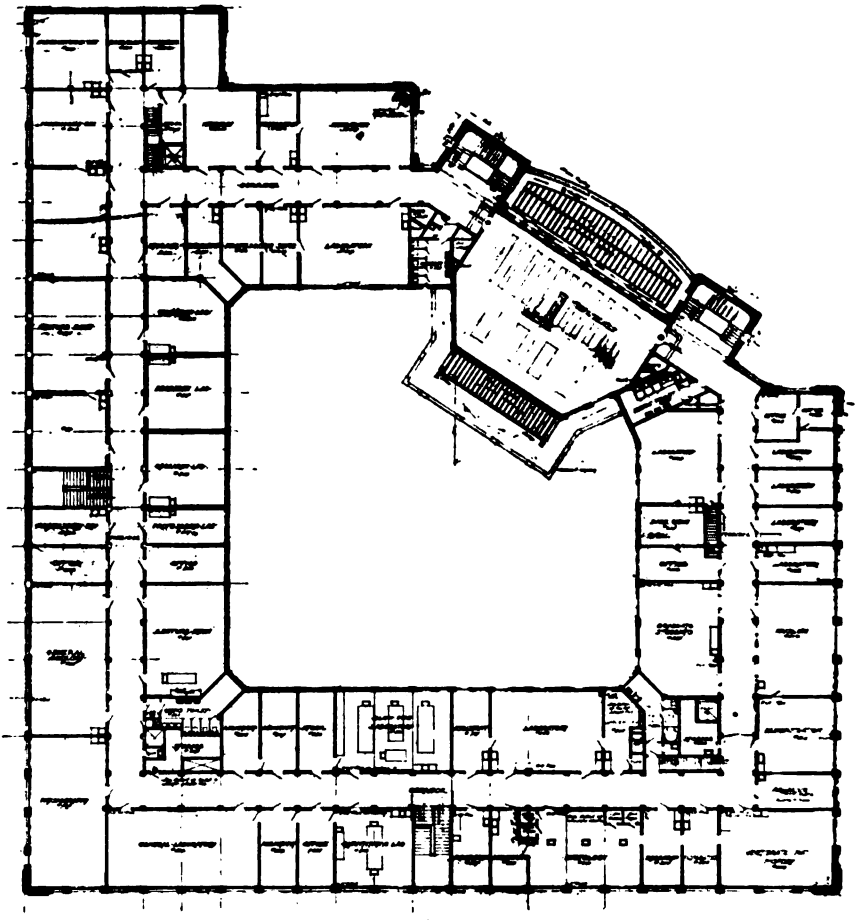
The location of the Science Hall is to be in the space between the Law and Chemistry Buildings across from the Hill Auditorium. This required that the old frame structure housing the Homoeopathic offices and the Department of Psychology be removed. This removal has been carried out and the excavation and construction of the lower floors actively taken up. A great deal of care and thought was necessary to so place the building that it would possess maximum size for the space covered, and still not interfere with the "Holy of Holies";—Michigan's Diagonal Walk. As may be seen in the accompanying first floor plan, the problem was solved by placing the Auditorium across one corner of the building.

The size of the building is such as to make it exceed that of the present new Engineering Building, which has heretofore been the largest. The New Science Hall, when completed, will measure 262 feet, 8 inches on the East side and 149 feet, 4 inches on the West side. The North side will measure 243 feet, 6 inches, while the South side will have a total length of 117 feet. A space of 17 feet will separate the building and the diagonal walk. The court, about which the building will be erected, will measure 118 by 121 feet. There will be four floors in addition to the basement. In all there will be 155,000 square feet of floor space in the New Engineering Building.

The building proper will be constructed of red brick and terra cotta, as in the Hill Auditorium. It will differ from the conventional University building in two ways;—first, it will be constructed on the unit system, whereby the building is supported on a series of uniformly spaced reinforced concrete piers; second, it will use every available inch of wall space for win-

Digitized by Google

dows. In adopting these most modern developments of Concrete Construction, the appearance of the building will resemble to a more or less extent, the latest factories. Reference to the accompanying illustration will show clearly these schemes of construction, making a building neither severe nor fantastic, but beautiful in its simplicity. The exterior ornamentation will be carried out in terra cotta and tapestry brickwork.



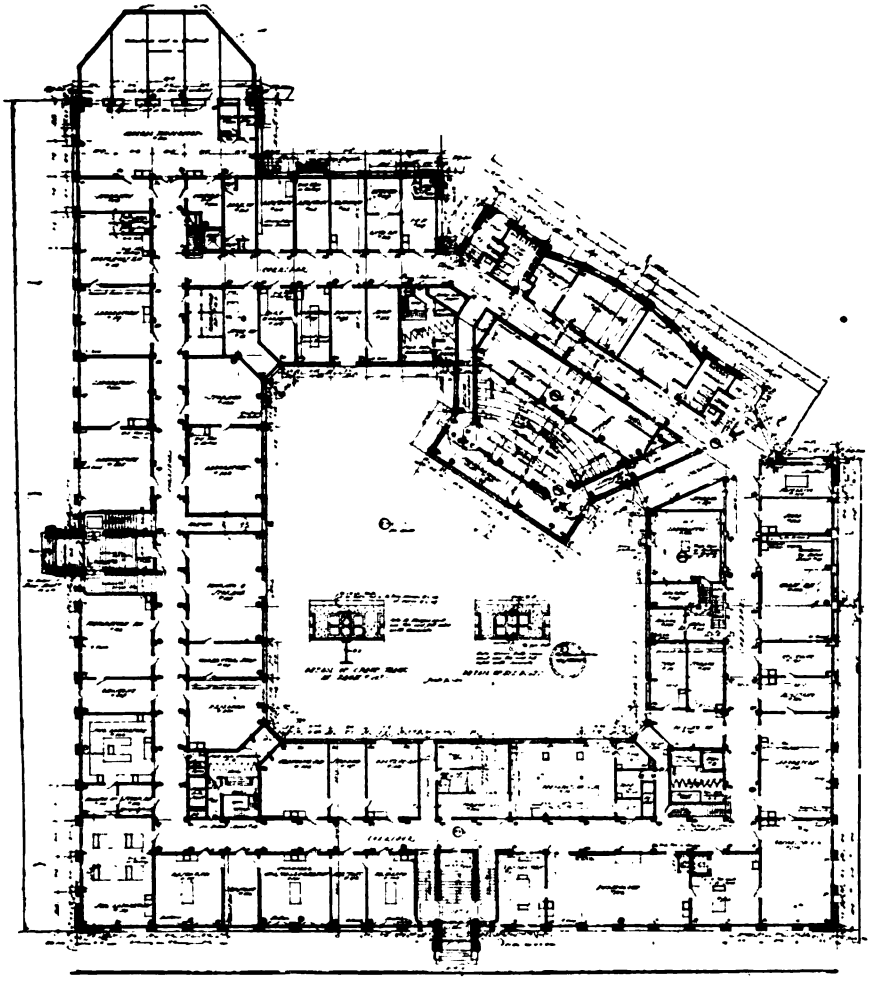
GROUND FLOOR PLAN

The foundation, as before mentioned, will consist of a series of reinforced concrete piers spaced uniformly at a distance to allow of offices of width 11 feet, 6 inches between each pair of piers. In this way, the offices will be of this width or multiples of it. The partitions are to be merely curtain walls so that alterations may be made at any time and at little expense. The rooms on each side of the central hall will measure about 23 feet in length, leaving a passageway 10 feet four inches in width.

The interior of the building will be finished with plastered walls and cement floors. The halls will probably be finished in terazzo. There will be

Digitized by Google

but very little wood used in the construction of the entire building; the oaken doors being the only instance. The window frames will, in all likelihood be of steel instead of the usual wood, to carry out the factory scheme of getting the most light out of a given wall space.



SECOND FLOOR PLAN

USES AND EQUIPMENT.

The six departments mentioned at the beginning will each be housed in a separate section of the building, running from the top to bottom. In this way the equipment and apparatus for each branch of science will be so centralized as to facilitate study and research in the most efficient way. On the South side, for the especial benefit of the Botanical department, will be built a greenhouse 30 by 60 feet. To aid in the work of the Zoological and Botanical departments, there will be four constant temperature rooms in which the temperature may be varied from 28 to 90 degrees Fahrenheit.

Digitized by Google

These departments will have caves in the basement for the growing and storing of plants and supplies. Some of the caves will be devoted to the study of the habits of underground animals, an extremely interesting phase of science.

The museum of the Geological and Mineralogical departments will be located in the building and will be open to the general public. This will be a great improvement over the old order of things. The Library will be the best equipped departmental library on the campus, and is designed to contain 30,000 volumes. These will be housed in double tiered racks. The Library will be lighted by the indirect system. The air used in the building will be filtered, thus ensuring health and cleanliness.

The Amphitheatre will be one of the most valuable features of the building. It will hold about 500 and will be equipped with the most modern accessories. The lighting is by means of indirect illumination. Special tables, movable and stationary, supplied with electricity, compressed air, gas and water, and furnished with the latest laboratory equipment for the performance of experiments of all kinds, will be located on the platform. Motion picture apparatus will be installed, making Michigan the first school to employ moving pictures in the actual instruction of students. There are many other new and valuable features which the New Science Building will possess but lack of space prevents a detailed description here.

As the estimated cost of the completed building is about $400,000 and the appropriation is for but $375,000, the top floor will be left unfinished for the time being. This will be left in such shape that the work may be carried through to completion at any time in the future.

The New Science Building, as it is on paper and will be in reality, will stand as a monument to the spirit of progress which permeates the atmosphere at Ann Arbor, and is but another step toward the placing of Michigan at the head of the American Universities.

Digitized by Google

ONE, TWO AND THREE HINGE ARCHES*

F. A. STEIGER

Arch Hinged at Crown.

The expressions which represent equilibrium in an arch hinged at the crown are, $+Ao_1 i$ for one-half equals $-Ao_1 i$ for the other half, and $\Sigma (z i) = \Sigma (Ao_1 - Po_1) z$ for each half are equal.

Here Ao_1 and Po_1 are the distances downward, from a horizontal line through the hinge, to the arch central line and to the proper moment polygon respectively, $Ao_1 - Po_1$ being equal to the intercept i. Here also z is the horizontal distance from the center (hinge) each way to the ordinates at the "a" points. The Ao_1 ordinates are obtained by subtracting the arch ordinates AO from the arch center height R, and the z distances are known so we have only to solve to find the Po_1 ordinates.

ONE HINGE ARCH
TABLE 1

1	2	3	4	5	6	7	8	9	10	11
Load Points	L & D Lds.	Points	D. Lds.	Comb. Lds.	Σ lds.	Spaces	Moments	Σ Moments (Downward)	Trial Po_1 H=100,000	"a" Points
11	1880	11	1220	3100	3100	3.30	10230	10230	.1023	10
10	0	12	0	0	3100	3.30	10230	20460		
9	3880	13	2580	6460	9560	3.20	30592	51052	.5105	8
8	0	14	0	0	9560	3.70	35372	86424		
7	4700	15	3300	8000	17560	3.30	57948	144372	1.4437	6
6	0	16	0	0	17560	4.40	77264	221636		
5	6720	17	5100	11820	29380	3.70	108706	330342	3.3034	4
4	0	18	0	0	29380	5.30	155714	486056		
3	11300	19	9340	20640	50020	4.50	225090	711146	7.1115	2
2	0	20	0	0	50020	2.80	140056	851202		
1	8330	21	7270	15600	65620	2.50	164050	1,015,252	10.1525	A
A	36810	B	28810	65620			1,015,252			

Given loads and spaces to find trial ordinates, Po,

Our problem assumes an eccentric load but if we double this eccentric load, reversing the direction of our loadings, then, as our load is symmetrical about the hinge, $\Sigma Ao_1 i = 0$ for each half; that is, there is no horizontal movement of the hinge.

As the intercepts $i = Ao_1 - Po_1$ then $\Sigma Ao_1 i =$

$$\Sigma [(Ao_1)^2 - (Ao_1 Po_1)] = 0$$

or,

$$\Sigma (Ao_1)^2 = \Sigma (Ao_1 Po_1)$$

In this expression the arch ordinates Ao_1 are known so we must find the polygon ordinates corresponding to a trial polygon and, having tested these by the above equation and found the proportional error, we thereby

* Mr. Steiger had an article in the May, 1914, issue concerning the "Hingeless Elastic Arch," which offers some very interesting comparisons with the present type of arches discussed in this series of articles.—Editor.

Digitized by Google

find the true Po_1 and the true H for this doubled load, one-half of which is our desired H for the given load.

To do this we form Table I, in Col 5 of which the loads on the right half of the arch are combined with those on the left half giving us one-half of a system of symmetrical loads from which we are able to figure the bending moments due to these loads and spacings. As both sides of the arch are loaded alike we have only to figure the moments on one-half the system. Also, as our arch is fixed at the abutments and hinged in the center, so we must figure our bending moments and corresponding ordinates as in a beam fixed at one end and free at the other. To do this we continue Table I in which Col. 6 is the partial summations of the loads in Col. 5; Col. 7 the spacing between these loads, taken toward the abutment; Col. 8 the moments (Col. 7 × Col. 6); and Col. 9 the partial summations of these

TABLE 2

1	2	3	4	5	6	7	8	9
"a" Points	Ao	$(Ao_1)^2$	Trial Po_1	$Po \times Ao$	(4)×.96712 True Po_1	(2)−(6) $Ao_1 - Po_1$ = i	$Ao_1 \times i$	$\Sigma \times i$
10	.10	.0100	.1023	.0102	.0989	+.0011	+.0001	+.0036
8	.99	.2401	.5105	.2501	.4937	−.0037	−.0018	−.0363
6	1.36	1.8496	1.4937	1.9634	1.3962	−.0362	−.0492	−.6082
4	3.14	9.8596	3.3034	10.3727	3.1948	−.0548	−.1721	−1.3645
2	6.91	47.7481	7.1115	49.1405	6.8777	+.0323	+.2232	+1.1208
(A)		59.7074	(10.1525)	61.7369	(9.8187)	(+.1813)	+.2233	−.8845
							−.2231	Right half the same.

To test trial ordinates Po_1 and get true H

$\frac{59.7074}{61.7369} = .96712$

Trial $Po_1 \times .96712 =$ True Po

Test of polygon under assumed doubled load

$\frac{100.000}{.96712} = 103399.8 = H$ for doubled load.

$\frac{103399.8}{2} = 51699.9 = H$ for given load.

moments made *downward*. (Note that in the solution of the other three forms of arches these summations are made upwards.) As these summations are made downwards the numbers in Col. 9 are proportional to the ordinates from a horizontal line through the hinge *down* to the moment polygon, not at the corresponding load points, but at the next points toward the abutment, so that the final number corresponds to the height of the center point above the abutment end of the polygon. As the summations in Col. 9 correspond to bending moments, if we divide these by an assumed H, say 100,000, we get the trial ordinates as in Col. 10. As we only need the ordinates at the "a" points we have only figured these, and in Col. 2 have put the proper point numbers to which they correspond.

Having our trial ordinates Po_1 we now form Table II which needs no explanation. The footings of Cols. 3 and 5 give us the means of comparing $\Sigma (Ao_1)^2$ with $\Sigma (Ao_1 Po_1)$ and arriving at the proportional error. We have no need of finding the true ordinates Po_1 under this assumed double load but, as a matter of interest, we have carried out the table, and in Cols. 8 and 9 prove that the equations of conditions are satisfied. The footing of

Digitized by Google

ONE HINGE ARCH

TABLE 3

Given Loads, spaces and true H to find true intercepts i.

Moment Table – Loads left of center

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Points	Left Lds	Σ Lds.	Spaces	Moments	Σ Moments (abbreviated)	"a" Points	Trial Po, H=51699	Σ Arms	(9) × (8) Σ × Po	$(\Sigma)^2$	Triangle Intercepts	(8) + (12) True Po	Ao,	True i	(14) × (15) $Ao \times i$	(9) × (15) $\Sigma \times i$
11	1880	1880	330	6204	6204	10	.1200	3.30	.3960	10.89	−.0909	.0291	.10	+.0709	+.0071	+.2340
10	0	1880	330	6204	12408											
9	3880	5760	320	18432	30840	8	.5965	9.80	5.8457	96.04	−.2699	.3266	.49	+.1634	+.0801	+1.6013
8	0	5760	370	21312	52152											
7	4700	10460	330	34518	86670	6	1.6764	16.80	28.1635	282.27	−.4627	1.2137	1.36	+.1463	+.1990	+2.4578
6	0	10460	440	46024	132694											
5	6720	17180	370	63566	196260	4	3.7961	24.90	94.5229	620.01	−.6858	3.1103	3.14	+.0297	+.0933	+.7395
4	0	17180	530	91054	287314											
3	11300	28480	450	128160	415474	2	8.0363	34.70	278.8596	1204.09	−.9557	7.0806	6.91	−.1706	−1.1788	−5.9198
2	0	28480	280	79744	495218										(−1.1789	(−.59198
1	8330	36810	250	92025	587243	A	(11.3587)	(40.00)			(−1.1017)	(10.2570)	(10.00)	(−.2570)	+.3795	+.50326
(A)	(36810)								407.7877	2213.27					−.7994	−.8872

Moment Table – Loads right of center.

	Right Lds															
11	1220	1220	330	4026	4026	12	.0779	3.30	.2571		+.0909	.1688	.10	−.0688	−.0069	−.2270
12	0	1220	330	4026	8052											
13	2580	3800	320	12160	20212	14	.3909	9.80	3.8308		+.2699	.6608	.49	−.1708	−.0837	−1.6738
14	0	3800	370	14060	34272											
15	3300	7100	330	23430	57702	16	1.1161	16.80	18.7505		+.4627	1.5788	1.36	−.2188	−.2976	−3.6758
16	0	7100	440	31240	88942											
17	5100	12200	370	45140	134082	18	2.5935	24.90	64.5781		+.6858	3.2793	3.14	−.1393	−.4374	−3.4686
18	0	12200	530	64660	198742											
19	9340	21540	450	96930	295672	20	5.7190	34.70	198.4493		+.9557	6.6747	6.91	+.2353	+1.6259	+8.1649
20	0	21540	280	60312	355984										(+1.6259	(−9.0453
21	7270	28810	250	72025	428009	B	(8.2787)	(40.00)			+(1.1017)	(9.3804)	(10.00)	(+.6196)	−.8256)	+8.1649
(B)	(28810)								285.8658	2213.27					+.8003	−.8804

$\Sigma(z \times Po_1)$ Left should equal $\Sigma(z \times Po_1)$ right

407.7877 − 285.8658 = 121.9219 = unbalanced moment, M

Triangle intercepts $= \frac{M}{2\Sigma(z^2)} z = \frac{121.9219}{2 \times 2213.27} = .02754\, z$

Col. (9) × .02754 = Col. (12)

Proof of results

$-\Sigma(Ao\, i)$ Left $= +\Sigma(Ao\, i)$ Right

and $\Sigma \times i$ Right & Left are equal

Digitized by Google

Col. 5 being greater than the footing of Col. 3, we see that our trial ordinates are too large; that is, trial H is too small so we correct it accordingly and, dividing by two, we get the true H for our given eccentric load.

With our given loads and spaces and knowing our true H we might form an infinite number of corresponding polygons, but there is only one which will pass through the hinge and make $\Sigma\,(Ao_1 - Po_1)\,z$ for the left half equal $\Sigma\,(Ao_1 - Po_1)\,z$ for the right half. To find this polygon we form Table III. This table is in two parts, corresponding to the two halves of the arch. In the upper part we have the loads, moments and ordinates corresponding to the combined live and dead loads on the left half, and in the lower part the loads, moments and ordinates corresponding to the right half of the arch. From what has gone before it will not be necessary to explain this table out to Col. 8 except to note that the moments in Col. 6 are divided by the true H, previously found, to obtain the ordinates in Col. 8. We must test and correct these ordinates to make $\Sigma\,(Ao_1 - Po_1)\,z$ the same for either half.

$$\Sigma\,(Ao_1 - Po_1)\,z\ \text{Right} = \Sigma\,(Ao_1 - Po_1)\,z\ \text{Left}$$
$$\Sigma\,(Ao_1)\,z - \Sigma\,(Po_1)\,z\ \text{Right} = \Sigma\,(Ao_1)\,z - \Sigma\,(Po_1)\,z\ \text{Left}$$
$$\text{but}\quad \Sigma\,(Ao_1)\,z\ \text{Right} = \Sigma\,(Ao_1)\,z\ \text{Left}$$
$$\therefore -\Sigma\,(Po_1)\,z\ \text{Right} = -\Sigma\,(Po_1)\,z\ \text{Left}$$

The footings of the two parts of Col. 8 give us the means of comparing the $\Sigma\,(z \times Po_1)$ moments in each half and by subtraction to find the unbalanced moment, 121.9219.

The sum of the moments of the loaded half are too great so the trial polygon indicated by $A_1\,C\,B_1$ in Fig I must be swung on the hinge to the true position as indicated by the polygon $A_{11}\,C\,B_{11}$. The alterations in the lengths of the ordinates are proportional to the intercepts in the triangles $A_1\,D_1\,A_{11}$ and $B_1\,D_1\,B_{11}$. These intercepts are equal to $M/2\,\Sigma(Z^2)z$ where M is the unbalanced moment.

In Col. 12 we have these intercepts which we have taken from the trial Po_1 in the left half and added to the trial Po_1 in the right half to give the true Po_1 in Col. 13. Subtracting these from the corresponding Ao_1 we get the true intercepts i in Col. 15. By the footings of Cols. 16 and 17 we see that our equations of conditions are satisfied and our solution is correct.

Two Hinged Arch.

In an arch having two hinges placed at the abutments our proper moment polygon must pass through the hinges and, as the polygon cannot pass beyond the lines of the end reactions which pass through the hinges, it is therefore limited by the hinges, and two polygon closing line falls on the arch spring line.

Of the many polygons which might be drawn passing through the hinges we must seek that one which will make $\Sigma\,y\,i = \Sigma(AO^1\,i) = 0$ as,

$$i = AO - PO$$
$$\Sigma\,yi = \Sigma\,[(AO)^2 - (AO\,PO)] = 0$$

or,

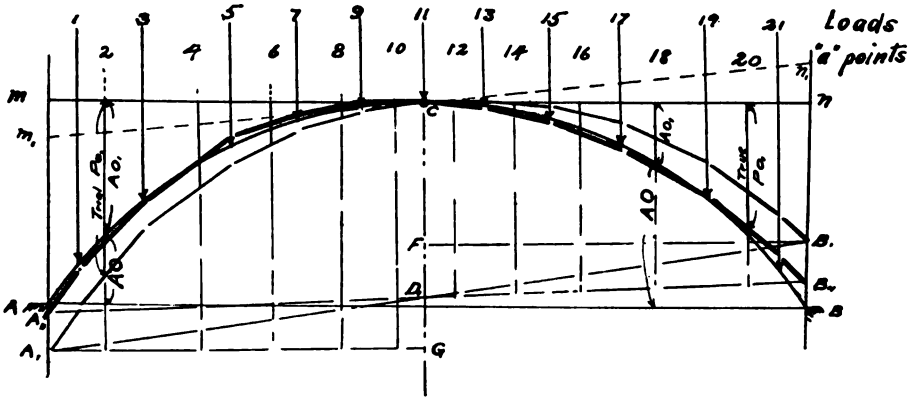
$$\Sigma\,(AO)^2 = \Sigma\,(AO\,PO)$$

In this equation the PO ordinates are the only unknowns. These we determine by finding the bending moments under our given loading and then

Digitized by Google

ONE HINGE ARCH

Fig. 1

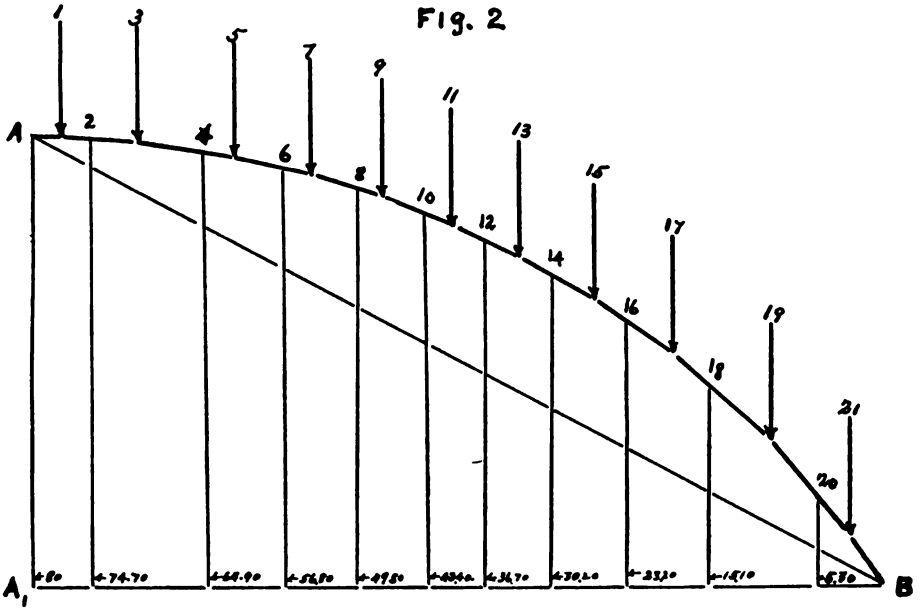


with a trial H we obtain a set of trial ordinates Po which, when applied in the formula, gives us the means of determining our ratio or error from which we are able to obtain our correct H and therefore the true polygon ordinates Po. As our spring line and our polygon closing line are identical, to get the desired intercepts i we have but to subtract the arch ordinates Ao from the corresponding true polygon ordinates PO.

If our loads were symmetrically placed on either side of the center point of the arch we would then obtain our bending moments by forming a moment table from the center toward one end, as the moments in both ends are similar under a symmetrical load.

TWO HINGE ARCH

Fig. 2



Digitized by Google

TWO HINGES
(First method)

Given Loads and spaces to find true intercepts i

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Points	L.&D Lds.	ΣLds.	Spaces	(4) x (3) Moments	ΣMoments (upward)	x Arms	$\frac{\text{Max. M.}}{\text{Span}} = \frac{2785566}{80}$ x Arms x Col. 7	(Col. 6)−(Col. 8)	Trial PO H=50000	A O	$(AO)^2$	(10) x (11) AO x PO	True PO = Trial PO x.99037	(14) − (11) True Intercept i	AO x i
(A)	0	0	2.50	0	2785566	80.00									
1	8330	8330	2.80	23324	2785566										
2	0	8330	4.50	37485	2762242	74.70	2,601 022	161220	3.2244	3.09	9.5481	9.9634	3.1933	+.1033	+.3192
3	11300	19630	5.30	104039	2724757										
4	0	19630	3.70	72631	2620718	64.90	2259790	360928	7.2186	6.86	47.0596	49.5196	7.1491	+.2891	+1.9832
5	6720	26350	4.40	115940	2548087										
6	0	26350	3.30	86955	2432147	56.80	1977752	454395	9.0879	8.64	74.6496	78.5194	9.0003	+3603	+3.1128
7	4700	31050	3.70	114885	2345192										
8	0	31050	3.20	99360	2230307	49.80	1734015	496292	9.9258	9.51	90.44	94.3944	9.8302	+3202	+3.0451
9	3880	34930	3.30	115269	2130947										
10	0	34930	3.30	115269	2015678	43.30	1507688	507990	10.1598	9.90	98.01	100.5820	10.0620	+1620	+1.6038
11	3100	38030	3.30	125499	1900409	(40.00)	(1392783)	(507626)	(10.1525)						
12	0	38030	3.30	125499	1774910	36.70	1277878	497032	9.9406	9.90	98.01	98.4119	9.8449	−.0551	−.5455
13	2580	40610	3.20	129952	1649411										
14	0	40610	3.70	150257	1519459	30.20	1051551	467908	9.3581	9.51	90.44	88.9955	9.2680	−.2420	−.23014
15	3300	43910	3.30	144903	1369202										
16	0	43910	4.40	193204	1224299	23.20	807814	416485	8.3297	8.64	74.6496	71.9686	8.2495	−.3905	−3.3739
17	5100	49010	3.70	181337	1031095										
18	0	49010	5.30	259753	849758	15.10	525776	323982	6.4796	6.86	47.0596	44.4500	6.4172	−.4428	−3.0376
19	9340	58350	4.50	262575	590005										
20	0	58350	2.80	163380	327430	5.30	184544	142886	2.8577	3.09	9.5481	8.8303	2.8302	−.2598	−.8029
21	7270	65620	2.50	164050	164050										+10.0636
(B)				2785566							639.4146	645.6351			−10.0613

$\frac{2785566}{80} = 34819.575^{-} =$ Vertical reaction at A

$\frac{639.4146}{645.6351} = .99037$

$\text{True } H = \frac{50000}{.99037} = 50486$

Digitized by Google

TWO HINGES (Second Method)

Given Loads, spaces and vertical end reactions to find true intercepts i

1	2	3	4	5	6	7	8	9	10	11	12	13
Points	L.b.d.Ld.	Σ Lds.	Spaces	(4) × (3) Moments	Σ Moments (upwards)	Trial PO H = 50000	AO	$(AO)^2$	(8) × (7) AO × PO	True PO = Trial PO × .99037	(11) − (8) True Intercepts i	(8) × (12) AO × i (y i)
9	3770	3700	3.20	12062	508369							
8	0	3700	3.70	13949	496305	9.9261	9.51	90.44	94.3972	9.8305	+.3205	+3.0480
7	4700	8470	3.30	27951	482356							
6	0	8470	4.40	37268	454405	9.0881	8.64	74.6496	78.5212	9.0005	+.3605	+3.1147
5	6720	15190	3.70	56203	417137							
4	0	15190	5.30	80507	360934	7.2187	6.86	47.0596	49.5203	7.1492	+.2892	+1.9839
3	11300	26490	4.50	119205	280427							
2	0	26490	2.80	47172	161222	3.2244	3.09	9.5481	9.9634	3.1933	+.1033	+.3192
1	8330	34820	2.50	87050	87050							
(A)	34820			508369								
9	110	110	3.30	363	508335							
10	0	110	3.30	363	507972	10.1594	9.90	98.01	100.5781	10.0616	+.1616	+1.5998
11	3100	3210	3.30	10593	507609	(10.1522)						
12	0	3210	3.30	10593	497016	9.9403	9.90	98.01	98.4090	9.8446	−.0554	−.5485
13	2580	5790	3.20	18528	486423							
14	0	5790	3.70	21423	467895	9.3579	9.51	90.44	88.9936	9.2678	−.2422	−2.3033
15	3300	9090	3.30	29997	446472							
16	0	9090	4.40	39996	416475	8.3295	8.64	74.6496	71.9669	9.2493	−.3907	−3.3757
17	5100	14190	3.70	52503	376479							
18	0	14190	5.30	75207	323976	6.4795	6.86	47.0596	44.4494	6.4171	−.4429	−3.0383
19	9340	23530	4.50	105885	248769							
20	0	23530	2.80	65884	142884	2.8577	3.09	9.5481	8.8303	2.8302	−.2598	−.8029
21	7270	30800	2.50	77000	77000							+10.0656
(B)	30800			508335				639.4146	645.6294			−10.0687

Digitized by Google

34820 = Vertical reaction at A
30800 " " " B
Load 9 divides and part goes to each abutment.

$$\frac{639.4146}{645.6294} = .99037$$

$$\text{True } H = \frac{50000}{.99037} = 50486$$

Having an eccentric load, to find the desired bending moments we may use one of several methods. We may form a full moment table of the loads and spaces, beginning at one end, as in table for two hinged arch marked (first method), or in the case of a simple system of loads where the vertical end reactions, at the abutments, are easily figured we may divide our moment table into two parts as in the table marked (second method). Considering the first method, in the table Cols. 1 to 6 need no explanation. As Col. 6 gives the bending moments down to a horizontal line $A_1 B$ through the end of the polygon, at point B, while the true closing line would connect the ends of the polygon, points A and B, we must then reduce these moments by amounts proportional to the intercepts of the ordinates between these two closing lines. Fig. 2 illustrates this condition. To do this we divide the moment at point $A = 2{,}785{,}566$ by 80, the span length, and multiply by the X arms beginning at the opposite end of our span than that from which our moment table was formed. This gives us Col. 8 and by subtracting Col. 8 from Col. 6 we get Col. 9, our true bending moments. Assuming H equal 50,000, by dividing into Col. 9, we get our trial PO in Col. 10. In Col. 11 we have our AO and in Col. 12 their squares from which we get $\Sigma(AO)^2$. In Col. 13 we have $AO \times PO$, the summation of which, when divided into $\Sigma(AO)^2$, gives us our proportional error with which we find our correct H and true PO, and by subtraction, $PO - AO$ in Col. 15, which we prove are correct by Col. 16.

The same results are obtained in the second table but with slightly less work. Taking our end reactions as 34820 at the left abutment and 30800 at the right we find that 3770 lbs. of load 9 goes to the left abutment and 110 lbs. to the right abutment. Fractions of a pound have been neglected. Starting at point 9 and forming our two moment tables in opposite directions we find as we should that at point 9 we have the same bending moment in each table. (The slight difference, 34 foot lbs., is due to neglecting the fraction of a pound in dividing load 9.) These are our true bending moments and need no correction so from this point we proceed to find our true ordinates and intercept as in the first method.

In using the third method we would form two moment tables starting at the center. As the loads on one half differ from those on the other half so our moments in the tables will differ, each set being down to its own horizontal closing line. The difference between the final or center moments

Digitized by Google

in each case we would then divide by the span length to obtain a factor, which, when multiplied by the X arms, toward and out from the center, gives us the corrections to be added to and subtracted from the corresponding moments in each half to find the true moments down to the true closing line.

In all these problems we may either deal with and correct our trial moments or we may convert them into ordinates first and then make the corrections.

The student will probably profit by plotting the polygon from the trial ordinates and then following the process graphically until it is thoroughly understood.

Three Hinged Arch.

To find the proper intercepts, i, in the problem of a three hinged arch we must find the moment polygon, corresponding to our given loads and

1	9	10	11	12
"9" Points	Moments	PO	AO	Intercepts
2	161220	3.1759	3.09	+.0859
4	360928	7.1101	6.86	+.2501
6	454395	8.9514	8.64	+.3114
8	496292	9.7767	9.51	+.2667
10	507990	10.0072	9.90	+.1072
(12)	(507626)	(10.0000)	(10.00)	.000
12	497032	9.7913	9.90	−.1087
14	467908	9.2176	9.51	−.2924
16	416485	8.2046	8.64	−.4354
18	323982	6.3823	6.86	−.4777
20	142886	2.8148	3.09	−.2752

spaces, which will pass through the three hinges. The third hinge may be at the center or otherwise.

Our problem is to find the ordinates, Po, of such a polygon, at the "a" points, from which the desired intercepts i are obtained by subtracting the corresponding arch ordinates, AO, from the calculated PO, and also to find the true H.

To do this we find the bending moments, as in a simple beam, from our given loads and spacings by means of a moment table, by either method explained for the two hinged arch, remembering, however, that the middle hinge must be included as a load point whether it has a load or not.

Having found our true bending moments we divide the moment at the middle hinge by the height of the hinge above the spring line, which is also

Digitized by Google

the polygon closing line. This gives us our true H at once, and by dividing this H into the bending moments at the "a" points, where the intercepts i are desired, we get the true PO from which we subtract the corresponding AO to find the true desired intercepts.

H and the intercepts i are derived in the following table. The moments in Col. 9 have been copied from Col. 9 of the table for the Two Hinge arch (first method) as they would be derived in the same manner and it is unnecessary to repeat the work. The moment at the hinge (Point II in this

	Hingeless	One Hinge	Two Hinge	Three Hinge
	H=51453	H=51700	H=50486	H=50763
Points	Intercepts "i"			
A	-.2822	-.2570		
2	-.1805	-.1706	+.1033	+.0859
4	+.0307	+.0297	+.2891	+.2501
6	+.1644	+.1463	+.3603	+.3114
8	+.1858	+.1634	+.3202	+.2667
10	+.0946	+.0709	+.1620	+.1072
12	-.0456	-.0688	-.0551	-.1087
14	-.1502	-.1708	-.2420	-.2924
16	-.2025	-.2188	-.3905	-.4354
18	-.1312	-.1393	-.4428	-.4777
20	+.2269	+.2353	-.2598	-.2752
B	+.5982	+.6196		
"(crown)	+.0239	.000	+.0547	.000

COMPARISON OF RESULTS

case) being divided by the rise of the arch center line 10, gives the true $H = 50762.6$. This being divided into the remaining moments gives the true PO.

COMPARISON OF RESULTS.

In the above table the figures for the Hingeless, One Hinge, Two Hinge, and Three Hinge arches are given for purposes of comparison. Those for the Hingeless Arch are given for the benefit of those who possess copies of the article published in the May, 1914 issue of the MICHIGAN TECHNIC, or who are sufficiently interested to desire to look it up. The whole table gives interesting data covering the four types of arches.

Digitized by Google

PERE MARQUETTE APPRAISAL

The Pere Marquette Railroad extends throughout the interior counties of the state and brings them into touch with the outer world and the principal markets. Without the Pere Marquette many localities in Michigan would have nowhere near their present development. Were it to be taken away, a serious handicap would befall the communities now served by it. It is, therefore, a property in which the people of the state are peculiarly interested, more so, perhaps, than in the trunk lines passing through the state, and doing comparatively little local business.

The Railroad Commission of the state are clothed with authority to authorize and approve stock and bond issues of all of the public service corporation properties of the state, and it will be necessary for this Commission to decide upon the amount of bonds and stocks which may be issued on the Pere Marquette road at the time of the coming reorganization which will necessarily follow the sale which has been ordered by the United States Court.

Under the provisions of the law, the Receivers of the road have requested that a valuation be made and the Railroad Commission have placed this work in charge of Dean Cooley of the Engineering. Department. A considerable number of University men are engaged upon the work in charge of the various branches and this brings the University into close touch with the Railroad Commission.

The civil engineering field work, including road, bridges, structures of all kinds, earthwork and all of the fixed property of the company is being appraised by a force of men under Professor H. E. Riggs of the Civil Engineering Department. Mr. A. J. Wenzell, '78E with six parties under his direction is in charge of the earthwork computations. Mr. A. R. Bailey, Instructor in Railway Engineering, is in charge of the office work in Detroit and is furnishing information to the roadway and structure inspectors, eight or ten in number, all of whom are experienced railroad engineers, graduates of various institutions.

Professor H. C. Anderson, Professor of Mechanical Engineering, has charge of the appraisal of motive power equipment and machinery, and among the members of his staff are Assistant Professors Fessenden and Verner and Mr. O. W. Boston, all of the Mechanical Engineering Department.

Professor David Friday of the Department of Economics has charge of the accounting staff and of the land valuation.

Professor Herbert C. Sadler, head of the Department of Marine Engineering, is making the apprisal of ferries, steamships and other floating equipment.

Professor L. M. Gram, Professor of Structural Engineering, has charge of the valuation of bridges.

There is perhaps no class of public work which is attracting more attention at the present time than valuation, and it is gratifying to know that the Michigan Railroad Commission turns to the University for this class of work.

Digitized by Google

RECLAMATION OF LOUISIANA'S SWAMPS AND PRAIRIE LANDS

ALLEN T. DUSENBURY, '04E

Situated in the delta of the Mississippi River in the southern portion of Louisiana is a body of alluvial land containing approximately ten million acres. Of this about seven million acres is timbered, but now partly denuded, the balance being open prairie covered only with dense growths of varied prairie grasses.

Small portions of this ten million acre tract are high enough for natural drainage, but the great majority of it lies only six inches to two feet above mean Gulf level, so that it must depend for its agricultural value upon artificial drainage. This extensive body of land occupies space which was once part of the Gulf of Mexico, a fact well established by geologists, and was formed by the deposition of silt brought down by the "Father of Waters" from the twenty-six States which comprise the great valley of the Mississippi. This formation is of very great depth, it sometimes being necessary to drill over three thousand feet before sand or rock are encountered. The exceeding richness of this Delta land is apparent from the fact that the soil which washes off the farms in the upper valley in times of heavy rains and floods is the choicest top soil, and thus the cream from all the farms in the Mississippi Valley has been transported to Louisiana to form this delta. A delta country is rich accordingly as the valley through which the river flows which forms it, and as the valley of the Mississippi is conceded to be the most fertile valley on the face of the earth, this portion of Louisiana can not be less rich than the famed deltas of the Rhine and the river Nile.

In spite of the amazing fertility of this land, only a very small quantity of it has as yet been put to agricultural use, this portion consisting of strips ranging from one-quarter of a mile to one mile in width bordering on the Mississippi River, the Bayous Lafourche and Teche, and a few smaller streams which were once affluents of the Mississippi Although for many years past quite a number of the plantations fronting on these streams have used artificial means to aid in their drainage, it has only been a few years since the reclamation of the prairie drainage was depended upon entirely. But now enough of this land has been thoroughly reclaimed and put in a high state of cultivation, by farmers from the North and West, to prove the entire feasibility of the undertaking, and at present there are many men and corporations engaged in the work of changing these age-long haunts of the alligator and muskrat, and breeding places of mosquitoes into beautiful and highly productive farms.

The reclamation of this delta land is an exceedingly simple proposition from an engineering standpoint. First a topographical survey is made and the boundaries of a tract to be included in a Reclamation Unit are

Digitized by Google

determined. Then a dredge boat is passed around the tract, the spoil from the canal dug by the dredge being thrown to the inside, thus forming a continuous levee which is built up till it is high enough to protect the land within from any outside overflow. Then a system of canals is dug within the leveed area, the canals serving the purpose of sumps or reservoirs into which the small surface ditches empty, and at the same time conducting the water to a pumping station.

This pumping station is located at a point which is best fitted for the needs of the particular tract and should have a sufficient capacity for removing a run off of one and one-half inches in twenty-four hours. The reservoir canals should also have a storage capacity of at least one inch of rainfall over the whole area, and when there is added to this the amount of water which will be temporarily absorbed by the land itself, it is only an exceedingly heavy rain which will not be readily taken care of.

The first unit reclaimed by the company with which the writer is associated, and which company is the pioneer in the Reclamation of the Wet Prairie Lands of Louisiana, contained about one thousand acres, but larger areas were afterwards treated, and now we have adopted five thousand acres as a unit best adapted for the work. Topographical conditions, however, will oftentimes make larger or smaller areas necessary. As it will be many years before an adequate railway system traverses the marshes of South Louisiana, and as this territory is already a net work of canals, bayous and lakes, water transportation must largely be depended upon, but when properly understood and utilized it is the cheapest method of transportation. The canal which surrounds each reclaimed tract is made a navigation canal, usually forty feet wide and eight feet deep, and this is made to connect with the general system of waterways so that each farmer, after no more than one mile haul by wagon, can place his produce on boats or barges and transport it to the sea, to the city of New Orleans or to some other desired shipping points.

Various types of pumping machinery have been used in this reclamation work. Paddle wheels, sometimes having as great a diameter as forty feet with paddles eight feet wide and making from three to five revolutions per minute have been used to some extent, as well as a crude type of vertical submerged centrifugal pump, but now the best practice requires horizontal centrifugal pumps designed for very low lifts, the larger sized pumps being direct connected to Corliss engines, the pumps and engines being usually mounted in duplicate on a concrete dam which is constructed across the main reservoir canal at its junction with an outfall canal or the bayou or lake on which the tract may border.

The total average rainfall in Southern Louisiana is about sixty inches per year, but as evaporation here is nearly equal to total rainfall, and as the growing crops would more than take up the balance if our rains were equitably distributed throughout the year, it might be

Digitized by Google

thought we would never need to start the pumps. However, this is not the case, our heaviest rains coming during the summer months, at which time most of the pumping takes place. Yet the pumps will seldom need to run more than thirty full days out of the whole year.

The reclamation of these lands has now arrived at the stage where experimental work is practically over and the costs fairly well established. In units of approximately five thousand acres, the total cost of reclamation, including levees, reservoirs, surface ditches, roads and pumping station should not exceed twenty-five dollars per acre. The cost of pumping based on conditions prevailing during the past few years should not exceed forty cents per acre per year, and this in comparison with costs of irrigation in most of the Western districts is almost negligible.

Louisiana is a magnificent State. It has wonderful natural resources including oil, gas, sulphur, salt, timber, oysters and a great many other varieties of sea food. Its oranges and grape fruit are unequalled and a great variety of other fruits flourish. If one must endure the climate of any one section of the country the year round, I know of no place equaling southern Louisiana, and, with the exceeding fertility of its soil, when this portion of the State is fully developed, as it will be in a very few years, I believe it is destined to become the garden spot of the whole United States.

Digitized by Google

SELF INDUCTION OF TRANSFORMERS

PROF. GEORGE W. PATTERSON

THERE are two very different ways of considering the action of the transformer, that of the physicist and that of the electrical engineer. These ways are confusing to the student of electrical engineering because the expression "self induction" is used by both, but in different meanings. The object of this short paper is to make the facts clear in the hope that some one may be helped. Let us first take the physicist's view. The electromotive force produced in the secondary of a transformer is said to be due to changes in primary current acting by mutual induction on the secondary winding. The formula for this action is

$$e'_2 = -M \ di_1/dt, \qquad (1)$$

where M is the mutual inductance, i, the primary current and t the time. Part of the secondary e. m. f. is lost because of resistance r^2 and self inductance l_2 of the secondary winding, so that the terminal e. m. f. of the secondary is

$$e_2 = -M \ di_1/dt - l_2 \ di_2/dt - r_2 i_2. \qquad (2)$$

The electrical engineer does not accept formula (1), which states symbolically that the e. m. f. generated in the secondary is greater as i_1 is greater. The engineer believes the contrary to be true, for to him electromotive force is produced by rate of change of flux, and he would write equations (1) and (2) in a different form, viz.,

$$e''_2 = -N_2 \ d\phi_2/dt \qquad (1')$$
$$e_2 = -N_2 \ d\phi_2/dt - r_2 i_2 \qquad (2')$$

where N_2 is the number of turns in the secondry winding and ϕ_2 the flux linking with them. It will be noticed that the physicist considers that a larger secondary e. m. f. is produced and then part lost in secondary self inductance, while the engineer does not consider that this lost part was ever produced. Evidently we have the relation,

$$e''_2 = -N_2 \ d\phi_2/dt = -M \ di_1/dt - l_2 \ di_2/dt.$$

As primary and secondary currents in general are opposed, the last term is arithmetically a difference. The e. m. f. applied to the primary is expressed by the physicist (eddy currents in the core being ignored) as follows:

$$e_1 = r_1 i_1 + l_1 \ di_1/dt + M \ di_2/dt, \qquad (3)$$

and by the electrical engineer

$$e_1 = r_1 i_1 + N_1 \ d\phi_1/dt, \qquad (3')$$

where the symbols have the same meaning as before, i. e., i_1 indicates primary circuit, etc.

Digitized by Google

We know that there is some leakage of flux so that ϕ_1 and ϕ_2 differ. The equation may be written in another form

$$e_1 = r_1 i_1 + N_1 \, d\phi_2/dt + N_1 \, d(\phi_1 - \phi_2)/dt. \qquad (3'')$$

The leakage flux $\phi_1 - \phi_2$ produces the same effect in the primary e. m f. as would be produced by an equal flux linking with an inductive winding of the same number of turns in series with the primary, which, from the physicist's stand point might be represented by

$$L_1 \, di_1/dt = N_1 \, [d(\phi_1 - \phi_2)/dt]_2$$

where L_1 is only part of l_1.

The electrical engineer then writes the formula for primary applied e. m. f.

$$e_1 = r_1 i_1 + L_1 \, di_1/dt + N_1 \, d\phi_2/dt, \qquad (3''')$$

and he calls L_1 the self inductance of the primary circuit.

This formula may be expressed as a vector equation if e_1, i_1 and ϕ_2 are simple harmonic, as follows:

$$E_1 = r_1 I_1 + j L_1 \omega I_1 + j N_1 \omega \Phi_2$$

when E_1, I_1 and Φ_2 are maximum values and ω an angular velocity. It is usual to assume E_1 and I_1 as effective values and ϕ_2 as maximum value. In this case we must write the formula

$$E_1 = r_1 i_1 + j L_1 \omega I_1 + j \, N_1 \omega \Phi_2/\sqrt{2}; \qquad (4)$$

and for the secondary terminal e. m. f.

$$E_2 = -j \, N_2 \omega \phi_2/\sqrt{2} \, - r_2 I_2. \qquad (5)$$

These equations make no reference to self inductance in the secondary and ignore all except that part of what the physicist calls the selfinductance of the primary which is involved in leakage flux.

To say that either the physicist or the engineer is in error is a mistake. They are both right, but they do not agree in their definition of the term self inductance.

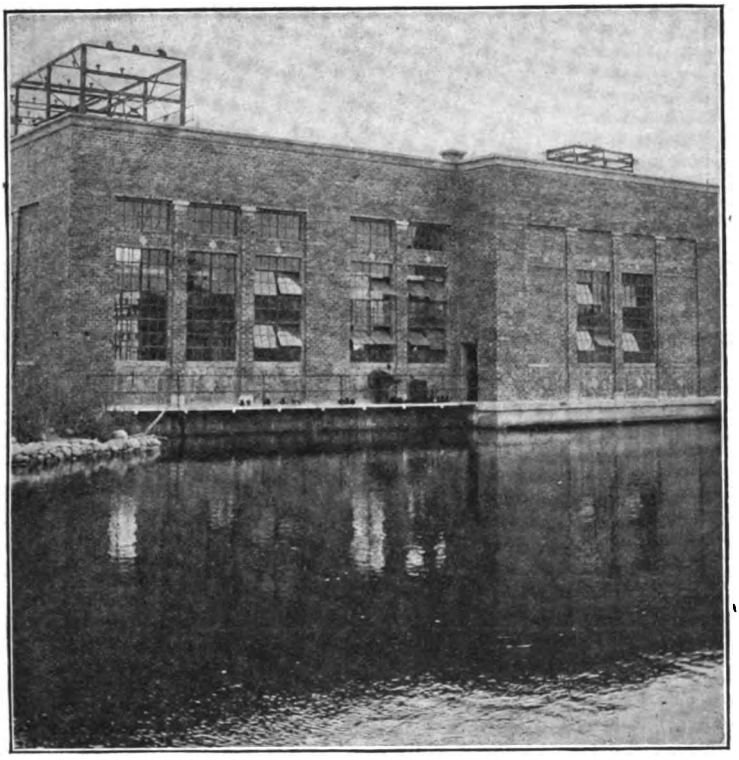
To take into account the effects of hysteresis and eddy currents in the core would require a much more complicated treatment of the subject. For this the reader is referred to the writings of Dr. Steinmetz and the other masters of the science.

Digitized by Google

THE ARGO PLANT

DON A. SMITH, '15 E

The new Argo plant of the Eastern Michigan Edison Company recently put into operation in Ann Arbor, is unique among electrical plants and of considerable interest to an engineer, for it combines the functions of a generating plant, a distributing station, and a railway feeder station, and includes what is probably the only water driven direct current generator in the country running parallel with a motor generator and feeding directly into a railroad trolley system.



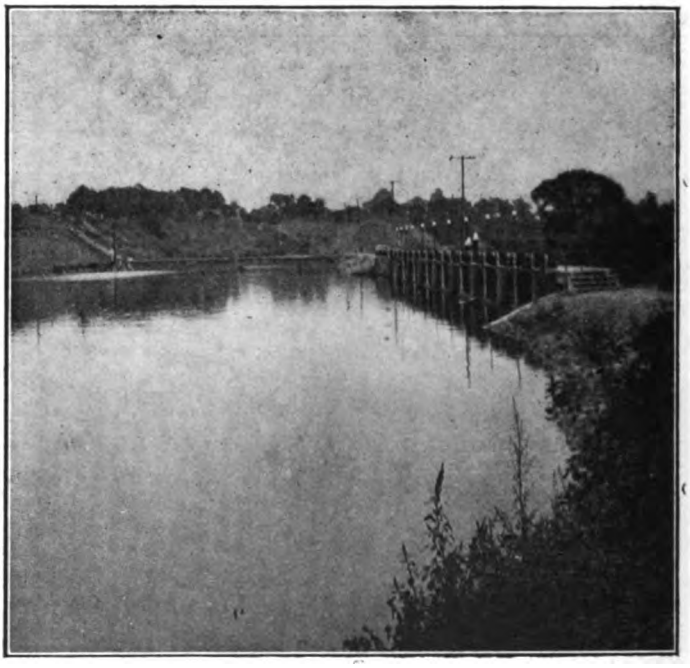
ARGO DAM POWER HOUSE

The Argo plant consists of a concrete dam about 200 feet long, built over and including in its construction the old Argo dam, and a power house having a rated generating capacity of 900 K. W. and a total D. U. R. capacity of 1450 K. W. A 14 foot head of water acts upon the turbines, which are of a type designed by Professor Zowski for the Allis-Chalmers Company of Milwaukee. Four high tension lines of the Eastern Michigan Edison Company, two from Detroit via Geddes, one from the Barton plant and one from Detroit by way of Whitmore Lake and South Lyons, feed into the plant, making it a switching station in the 23,000 volt circuit comprising the Washtenaw Division.

Digitized by Google

Generating Station.

As a generating station the Argo plant consists of two units of 450 K. W. capacity each, direct connected to hydraulic turbines, of 575 B. H. P., one unit generating alternating current at 2300 volts, the other direct current at 650 volts. In each unit the generator rests on the main floor and the turbines are placed 14 feet below the rotor and three feet above the level of the tail race. The weight of an entire rotating part of a unit is carried by a thrust bearing in the generator frame above the rotor. In addition to the thrust bearing there are three steady bearings, one above the rotor, one in the main floor and one above the turbine. The governor is placed between the A. C. and D. C. generators and may be attached to either, although as a rule the A. C. generator runs without a governor at a fixed gate opening approximating .8 and is controlled entirely from the switchboard.



Argo Dam

Motor Generators.

In addition to the turbine generators and the governor there are on the main floor a 35 K. W. exciter, driven by a 2300 volt A. C. motor, and two motor generators of 500 K. W. capacity for changing A. C. current to D. C. current for railroad power. Motor generators were installed in the Argo plant instead of rotary converters as in the other railroad sub-stations, to increase the power factor on the transmission system. By over exciting the field on the synchronous motors the power factor can be kept at about 85 or 90 which is considered very good on account of the large induction motors in use in Ann Arbor at some distance from the station. Without the motor generators on the line the power factor in the station runs at about 70.

Digitized by Google

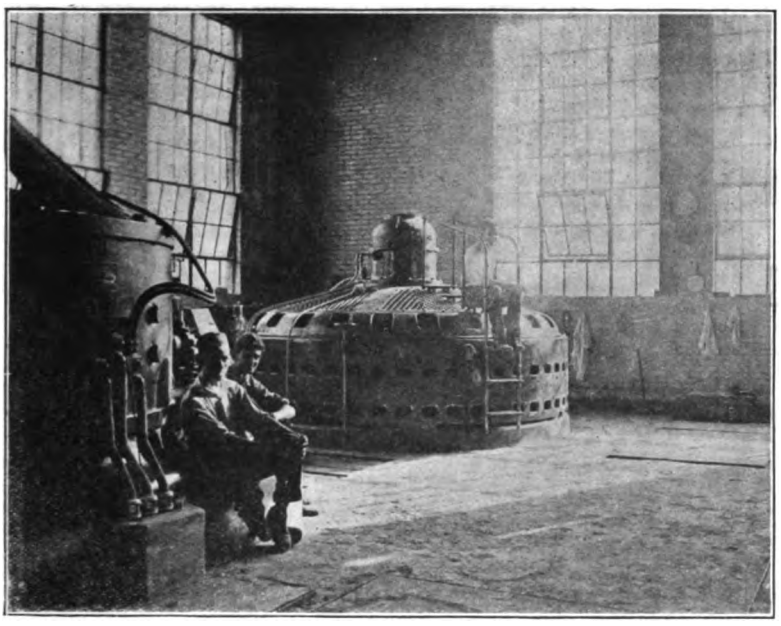
Distribution Station.

The load at the Argo plant for Ann Arbor light and power averages 700 or 800 K. W., with a maximum in winter of 1200 K. W. At nearly all periods, therefore, current must be taken from one or all of the four high tension lines coming in from other power houses. This current is stepped down from 23,000 volts to 2300 volts by three water cooled syphon system transformers of 1,000 K. W. capacity which are located in a separate room at the north end of the building. In this room are also high tension oil switches, and on a raised platform the 23,000 volt, four tank aluminum cell, lightning arrestors for the high tension lines entering the building.

The current for local purposes is taken off the switch busbar, which may be switched in with the A. C. generator and any or all of the feeders coming into the plant. The 2300 volt switches are located on a raised platform above the switch board as are also four automatic voltage regulators, two of 300 K. V. A. and two of 500 K. V. A. capacity. Six feeders carry three phase 60 cycle current out of the plant for commercial and power use in Ann Arbor.

Railroad Sub-Station.

As already stated the Argo plant is unique among railroad generating plants because of the operation of the D. C. water driven generator in parallel with the motor generator, and the linking of the two with the trolley and rail of the Detroit Jackson and Chicago Railroad at Ann Arbor. The Edison Company's engineers were divided as to the advisability of putting in this D. C. generator and there was some speculation as to its successful operation. The D. C. Generator is governed by the automatic opening and closing of the gates controlling the water



Interior View

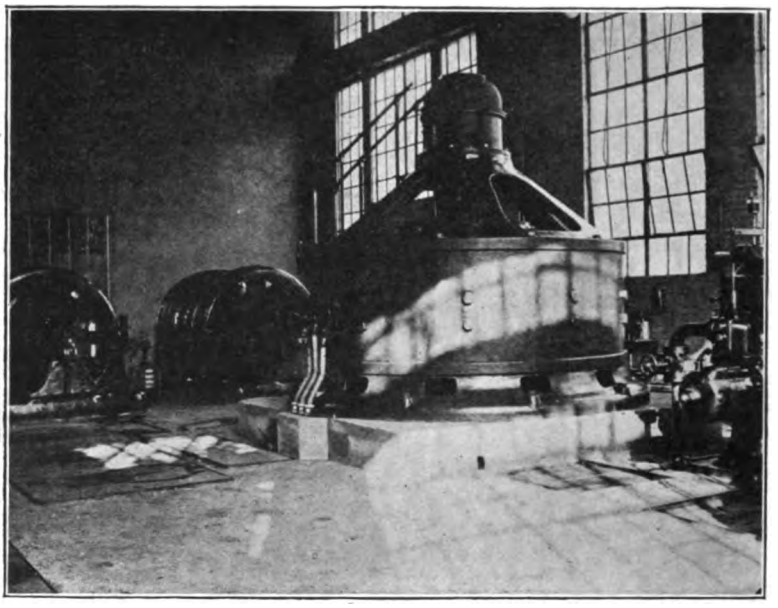
Digitized by Google

entering the wheel and it necessarily meets the changing load due to car movements less quickly than the synchronous motor driven generators. It was therefore impossible to tell exactly how the two would run in parallel.

In the short time, however, that the plant has been in operation it has been found that the D. C. generator runs in parallel with a motor generator, even better than the two motor generators will run in parallel together, and the governor opens and closes the gates to meet changing loads on the D. C. Generator, so quickly as to cause considerable erosion of the banks of the pond above the plant. When operating the water driven generator and the motor generator in parallel, the load on the water driven machine varies but little (400 to 600 amp.) and the motor generator takes the fluctuating load (0 to 1500 amp.) keeping the voltage on the line constant. When the load is light the water driven machine carries it entirely and the motor generator sends A. C. current back into the line.

It is surprising how well the motor generator runs from the D. C. end and generates A. C. Current in the Synchonous motor. This will work out very well at times of high water when the water driven machine can be run constantly at about full load.

The plant was designed by, and constructed under the superivision of Gardner S. Williams, U. of M., '89. Consulting Engineer. The Douglass Engineering Company of Detroit were the general contractors. The hydraulic machinery was furnished by the Allis-Chalmers Company of Milwaukee, Wis.; the electrical machinery by the General Electric Company, Schenectady, New York. Mr. Howard K. Holland, '08E, was resident engineer in charge of the work and Mr. George E. Lewis, '09E, is Division Superintendent of the Eastern Michigan Edison Company in charge of the plant at the present time.



LARGE GENERATOR—TURBINE DRIVEN

Digitized by Google

THE MICHIGAN TECHNIC

Old Engineering Bldg. **Ann Arbor, Mich.**

OFFICIAL ORGAN OF THE DEPARTMENT OF ENGINEERING OF THE UNIVERSITY OF MICHIGAN

Published quarterly in the months of October, December, March, and May by the Engineering Society

Vol. XXVII OCTOBER, 1914 Number 2

Publishing Staff

OLIVER W. HALL . . . Managing Editor
WM. C. THOMPSON . . Business Manager

Assistants

R. C. Glazier
H. W. Rix
L. C. Rowley
W. Brodhead
L. W. Lamb
W. S. Helmer
T. D. Weaver
A. E. Hecker
W. M. Riach
H. Simpson
D. A. Smith

Advisory Board

PROFESSOR E. M. BRAGG . . . . . Chairman
ASSISTANT PROFESSOR A. O. LEE . . . . . Secretary
MR. H. R. LLOYD . . . . . Treasurer
ASSISTANT PROFESSOR J. R. NELSON . . . Advisory Editor

EDITORIAL

FRESHMEN TAKE NOTICE!

FOREWORD FROM THE ASST. DEAN.

Students entering the Engineering Department often fail because they do not realize the size of their job. Some are poorly prepared in Mathematics and Language; others are well prepared but not serious-minded and willing to work to the limit. Engineering education today, contrasted with the training required twenty years ago, is like an automobile compared with the "one-hoss shay." To master engineering theories and modern practice in four years a student must make a flying start and keep up the pace with body and mind every day of his course. Every lesson must be learned and every task performed on schedule time or discouragement and defeat await the delinquent student. The studies of the course are so closely related and interdependent that absolute continuity is necessary. There is no time for an engineer to sow wild oats or revel in social distractions. He is from the first engaged in mastering

Digitized by Google

a difficult science and in securing a profession on which his future depends. The intense rivalry among engineers calls for the severest training and the greatest industry from the day of admission. If lessons in freshman mathematics and language are neglected and only half learned, failure in subsequent technical studies is certain. The worst failures come to students who enter with no fixed purpose and who "know it all" when they come to us. An earnest desire to master the engineering science and a willingness to work under competent instruction will bring success even to a student poorly prepared. Forget that you were the brightest boy in Podunk High School and realize the fact that you are entering deep waters in which you must rely on skilled pilots, if you wish success in College!

With good health, regular hours, and honest effort you will get value received for your expenditure of time and money, so that your day of graduation will mark the culmination of a great and successful struggle for mastery and the beginning of a brilliant professional career.

It is with great gratification that we take our pen, or rather typewriter in hand, and begin the publication of this second issue of the present volume. Even though the last issue was too late to get around among all of the students of the University, still it reached some of them; none of them has thrown anything as yet, so we take it as a good omen. Some of the letters which were received after the appearance of the first issue were extremely encouraging, coming as they did, from old grads who had been through the same troubles that we are now going through in printing the TECHNIC. In any event, it was a start and that counts for a great deal. With everybody pushing with us and standing back of us, we will put the MICHIGAN TECHNIC in the place it deserves among University publications.

We stand in the same place as a man driving an automobile some years ago in the West. In coming around a bend on a grade he ran into a frightfully steep hill, covered with gravel. In stopping to let a team pass he found himself unable to start again, although he had been going all right previous to his stop for the team. Just at that time, however, a cowboy on horseback came along, and , seeing the trouble, hitched his lariat about the front axle, looped the other end about the horn of his saddle and spoke to his pony. With the engine of the car running and the mighty tug that the pony gave in his first lunge, the car started and kept going without further aid. That's it! We can keep going after we get a good start, but throw us your lariat and give us a lift! Then stick around ready to keep boosting.

ENGINEERING SOCIETY.

The new plan for the organization of the Engineering Society was left out of the last issue through unavoidable circumstances. Briefly, the plan is to subdivide the former one society into a number of branch societies, each branch to represent its department. Thus there will be branches of the Mechanicals, Chemicals, Electricals, Civils, Navals, etc., each of which is a separate society in itself. Each society will have its own treasury, officers, organization, meetings, etc., but will be represented in the general society by its presiding officer. The general society will consist of the membership of all of the branches and will be governed by a committee composed of the

Digitized by Google

heads of the branch societies. One of these heads will be elected to be President of the General society, and, as such, will be able to govern the general society according to the ideas expressed in the sub-societies and transmitted by the sub-society heads.

In this way, the difficulty of getting all of the society members interested in one subject foreign to their line of interest will be avoided, and each branch will hold meetings of interest to the members alone. Of course, the meetings of any one branch will be open to any or all of the members of the other branches who may be interested in that particular line of work.

This plan was evolved only after a rigid investigation of all possible plans, taken, into consideration both this school and others. The Engineering society was a success in former days when the school was small and the interest concentrated. But the Society failed to grow with the school, and as a consequence, has lost out. It is believed that this plan will be a success, and the earnest cooperation and assistance of all the students, both old and new, is desired.

The War.

It is a very significant fact in the war abroad that Engineering is taking by far the greatest part in the warfare. Leaving out of consideration for the moment the frightful carnage and loss that is going on; a matter to be deeply regretted but which cannot be helped, it is interesting to see how modern science has applied recent inventions in the carrying on of the war. Air ships, both dirigibles and aeroplanes, have played a very valuable part in locating the weakest part of an opposso that the attack might be made to the best advantage. Aeroplanes, flying high at dusk have rendered invaluable service in collecting data for maps, etc. It is almost impossible to hit them with cannon, flying high and swift, so that they usually get what they want. They also are deadly when it comes to dropping bombs and explosives in desired localities.

Automobiles have evinced their popularity by the manner in which they have been confiscated and pressed into actual service of war. The generals of the opposing armies with their staffs use machines constantly in directing the battles, and messages are handled almost entirely by their aid. In a recent newspaper photograph, it was very noticeable that an American machine was being used as a carriage for small cannon by one of the armies. Sad as the war is, it is of interest to see how modern inventions are playing their parts.

Thanks!

The Technic board wishes to thank all of the contributors and members of the staff for their help and cooperation in getting together this and the preceding issue. Without their assistance it would be a hard row to plow, and we assure them of our appreciation.

Our Advertisers.

The advertisers who make this paper possible to a large extent, are not in the business for pleasure any more than we engineers. They are advertising for results, and when they don't get them they feel that there is no further use in advertising in the same place. We request that they be given careful consideration by all of our readers, as their wares are standards in their respective lines of work.

Digitized by Google

DEPARTMENTAL NOTES

RESEARCH WORK

A series of tests have been conducted in the Mechanical Laboratories by B. H. Stuck and C. J. Taylor, both of the 1914 Engineering class, to determine the coefficient of air friction in galvanized iron pipes for varying velocities and pipe sizes. Very little accurate data is to be found on this subject and practically no experimental data has been determined.

The pipe used was ordinary galvanized pipe such as is used for ventilating ducts. The longitudinal seams were interlock joints, and transverse connections, 2" slip joints. All points were painted and taped to minimize leakage. The air was delivered by a No. 4 Sirocco Blower driven by a D. C. shunt motor.

It was decided that the Pitot tube was the best means of measuring air velocity pressure and static pressure and the tube manufactured by the American Blower Company was accordingly adopted as the best fitted. The tests were conducted on a duct about 100 feet long in which three stations were marked off for readings, 40 ft. apart, and at least 10 ft. from any variation in shape of the pipe. In order to obtain the average velocities in the pipe, ten readings were taken, in vertical and horizontal planes. This was necessary because of varying velocity between the centre and outside air currents.

In order to read low velocities and static pressures manometers of unusual accuracy had to be provided. These were especially designed for this work and were made in the engineering shops. They were calibrated by means of the hook guage to give magnified readings of pressures to one two-thousandth of an inch, measured vertically on the liquid used in the manometer tube.

From the Continuity equation, the average velocity of air at all cross sections of the pipe must be equal; hence all head lost in friction is lost from the static pressure head. By measuring the static pressure at each of the three stations, this loss (h_s) was obtained over two separate lengths of pipe; then, by involving this value expressed in feet of the air flowing, with the length (L), perimeter (p), and area (A) of the pipe to which it applies, and the velocity of the air (V), according to the equation

$$h_s = fLPv^2/A2g$$

the coefficient (f) was determined.

The tests were conducted on 6" pipe, and tended to show an increased coefficient at decreased air velocities, rising very rapidly at velocities below 1500 ft. per min. At higher velocities the values were more nearly constant—at least up to 4500 ft. per min., which was the maximum speed attained in the tests.

Gas Fellowship Work.

The Michigan Gas Association has for 14 years maintained one or more fellowships in Gas Engineering at the University of Michigan and have also supported an experiment station at the works of the Ann Arbor Gas Company. One of the perplexing problems in gas manufacturing has been to free gas completely from finely suspended tar particles. Two years ago work on this was commenced at the experiment station and an attempt was made to apply high tension electric currents to the depositions of these fine particles. The work carried on by Mr. R. B. Rowley, '12E and F. W. Steere, '12E, has shown it was entirely possible to completely purify gas by this process. Work has been continued at the gas experiment station along the same lines during the present year and it has been shown that it is entirely feasible to purify illuminating gas from suspended particles at the rate of 25,000 feet an hour with the expenditure of only .2 KW in power. The results of this investigation were presented at the meeting of the Michigan Gas Association in September in a paper presented jointly by Professor White and R. B. Rowley and C. K. Wirth.

Mr. F. W. Steere has during the last year developed the process along somewhat dif-

Digitized by Google

ferent lines at the coke ovens of the Somet-Solvay Co. in Detroit. He has met with success in the application of the process to coke oven gas and also to the purification of producer gas. All of the gas used in the gas engine that runs the Ford Automobile plant in Detroit has for the last six months been purified by the Steere process. The apparatus has worked entirely satisfacorily and the process has a bright future. Mr. Steere is to present a paper describing his process at the meeting of the American Gas Institute in October.

INVESTIGATIONS BY PROFESSOR ZOWSKI.

Considerable discussion was brought about by the appearance of the Rees Roturbo Pumps of English design that were recently introduced into America by the Manistee Iron Works Company. Two of these pumps were bought last year for Campus fire protection. It was claimed that the "drooping power curve" which makes the overloading of the motor impossible, was obtainable only by the unusual form of the impeller of these pumps, this impeller being patented in all countries.

Investigations, however, were started last year in our laboratory and are as yet unfinished. They were made on a special pump designed by Professor Zowski and built for laboratory purposes and in this pump six impellers were tried. One question which in recent years has been very much discussed by engineers, both here and abroad, was whether it is possible to obtain the so-called "dropping power curve" with pumps of ordinary proportions by only giving the impeller vanes proper curvatures and angles. Professor Zowski's experiments have shown that the same conditions as hold in the Rees pumps are obtainable with ordinary forms of impellers if only the impeller vanes are designed properly.

Professor Benjamin Bailey of the electrical engineering faculty has been working on a new line of electric automobile starters, embodying his own patents, for the American Electric Starter Company, of Detroit, of which company he is chief engineer.

NEW FACULTY MEMBERS

Mr. J. A. Van den Broek, who has been appointed to the position in Engineering Mechanics made vacant by the resignation of Mr. Ladd, is a Hollander by birth. His early educational training was obtained in the high school of Middelharnis, his native city; and later, for a brief period, in a school in Germany. He came to this country in 1905, attracted by the democratic institutions and ideals of the American people. In the early summer of 1907 he went to Lawrence, where he settled down for a course in the civil engineering department of the University of Kansas.

The summer of 1911, following his graduation, was spent in the wilds of Vancouver and British Columbia, on a railroad survey, and the following winter in the office of Hedrick and Cochrane, a leading engineering firm in Kansas City engaged in large reinforced concrete construction. A visit to Holland occupied the following spring, during which time a position in the government engineering service in Dutch East Indies was offered him. He preferred America, however, and presently returned to this country, taking first a position with the Boston Bridge Company, and later a place in the bridge department of the Canadian Pacific Railway, at Montreal, which he now leaves to come to the University.

Mr. Van den Broek is highly regarded by those with whom he has been associated, and has made many friends. His interests have not been bounded by his day's work, but have extended especially to music and art and out door life. His chief recreations are tramping and canoeing, the latter sport especially being followed with enthusiasm.

The electrical engineering department staff will be strengthened next year by the coming of Mr. T. J. MacKavanagh, to be

Digitized by Google

Assistant Professor of Electrical Engineering. Professor MacKavanagh has been head of the Electrical Department of the Shawenegan Technical Institute for the last two years, during which time he has also conducted special investigations on electrical machinery and insulators, for the Shawenegan Falls Power Co., Canada. Previous to 1912, Professor MacKavanagh taught electrical engineering at the Nova Scotia Technical College, Halifax, Nova Scotia, coincidently serving as Chief Electrician of the cable ship Minia engaged in locating faults in cables under the Atlantic Ocean, and repairing them.

Professor MacKavanagh received his university education in Glasgow, Scotland. He is an expert in telegraphy and wireless, and has been engaged in many and various lines of engineering work, both electrical and mechanical. He is an enthusiastic and expert teacher, and his conscientious service will increase the power and efficiency of our electrical engineering department.

MICHIGAN MEN IN THE PRESS*

The annual meeting of the American Society for Testing Materials held at Atlantic City in July was attended by Professors White and Ware of the Chemical Engineering Department. Professor White presented a paper on "Volume Changes in Portland Cement and Concrete" which was a continuation of the results presented before the same society three years before. He also attended a meeting of the committee on coal sampling and analyses. Professor Ware presented a paper on the examination of "Chinese Wood Oil." This oil has of recent years come into prominence as a varnish oil. It is in some ways much superior to linseed oil for varnish making and had it not been for its introduction the price of varnish must have increased much during the last few years. Up to the present time there has been no satisfactory methods for analyzing this oil and determining whether it was adulterated. Professor Ware and Mr. C. L. Schumann in this paper present a simple and very satisfactory scheme of analysis. Professor Ware also attended the session of the committee on preservative coatings. Summaries of the papers follow.

* This list is not by any means complete. It is almost impossible to obtain data of all the articles published or written by Michigan Men, so that any information regarding same is earnestly solicited.

VOLUME CHANGES IN PORTLAND CEMENT AND CONCRETE.

By A. H. White.

Portland-cement structures retain their colloidal property of expanding when wetted and contracting when dried, even after 20 years' exposure to the weather, and after baking to 600° F. A bar of neat cement may be made to progressively expand or contract according to the choice of moisture conditions. It may be made by successive bakings to contract as much as 4.6 per cent. Cement bars containing sand do not contract readily on account of the interlocking of the aggregates. When such bars are dried they become more porous and, therefore, on immersion, more water can enter, so that new particles of cement clinker will be hydrated, with a still further resultant elongation of the bar. Bars of 1.3 sand mortar have by successive bakings and boilings been made to elongate 0.75 per cent. Bars cut from sidewalks taken up after 20 years' service have been made to elongate 0.175 per cent by successive immersions in water at room temperature. This elongation is as much as would be calculated for a rise in temperature of 300° F. It must be considered a grave source of danger to concrete highways in wet locations. Dense concrete, even when wet, does not contain any liquid water and does not suffer any expansion on freezing. Such concrete when measured while frozen will be found to have contracted at the same rate as cast iron. Porous concrete containing liquid water expands on freezing and does not return to its original length on thawing because of the wedging of the aggregates. Repeated freezings will thus cause progressive distintegration.

Digitized by Google

ADVERTISERS INDEX

Allis-Chalmers Co. 167
Ann Arbor Press 163
Ann Arbor Savings Bank 163
Campus Bootery ..... Cover 3
City Laundry 165
Eberbach & Son 165
G. H. Wild Co. 171
George Wahr ..... Cover 3
Indianapolis Engraving & Electrotyping Co. ..... Cover 2
Lufkin Rule Co. 163
Mack & Co. 165
MICHIGAN TECHNIC ..... Cover 3
Murphy Iron Works 169
Rentschler's 165
Sheehan & Co. 161
Students' Supply Store 171
University Ave. Pharmacy 171
University of Michigan ..... Cover 4
Wickes Boiler Co. 169

Students' Headquarters

..For Drawing Instruments and Supplies..

SHEEHAN & CO.

STUDENTS' BOOKSTORE

Digitized by Google

EXAMINATION OF CHINESE WOOD OIL.

By E. E. Ware and C. L. Schumann.

Ths paper deals with the development of two methods for the quantitative estimation of the adulteration of Chinese wood oil.

The principle upon which the first method is founded is the formation, in wood oil, of an isomeric glyceride that is insoluble in light petroleum ether. This reaction ordinarily takes place very slowly even in bright sunlight, but it may be accelerated by the addition of any one of a number of materials in small quantity. The precipitate may be filtered out, and the residue weighed after freeing from petroleum ether. This residue consists of the adulterant and the unaffected glyceride of the wood oil. The weight of the unaffected glyceride may be taken as 7 per cent of the weight of wood oil present.

The second method depends upon the insolubility in alcohol of the potassium soap of elaeomargaric acid. The precipitate may be filtered out and weighed, after drying in a non-oxidizing atmosphere.

The two methods show a degree of accuracy much better than the existing methods, and permit a fairly rapid estimation of the purity of samples of wood oil.

STRENGTH OF LIME MORTAR.

By W. E. Emley, '06E and S. E. Young.

In this paper is described an attempt to measure the compressive, tensile, shearing, and transverse strengths of lime mortar, and to ascertain how these values are affected by the numerous variables met with in practice, such as: chemical composition of the lime; kind and amount of sand; size and shape of test specimen; conditions under which the test specimen is stored; the effect of added materials, etc.

The results indicate that the strength developed by a specimen of lime mortar is affected by too many variables to be capable of accurate measurement in the laboratory, and that even if this were possible, there is no assurance that the results obtained would be comparable with those which might be expected in practice.

In the "Horseless Age" of date Aug. 19th appeared an article entitled "The Proper Angle for Venturi Tubes," written by a member of the faculty in the School of Auto Engineering, Mr. S. R. Thomas. He takes up the problem from an analytical point of view and discusses a series of experiments bearing on the subject. The article is well illustrated by photographs.

At the December meeting of the Society of Naval Architects to be held in New York City, Professor Herbert C. Sadler will present a paper on "The Expansion and Contraction of Ships Forms and the Effect upon Resistance." The paper will embody the results of investigations carried on in the naval tank for the past year and a half.

CHANGES IN COURSES AND FACULTY

The courses in Chemistry required of all engineering students have been materially modified during the past year. The course in Qualitative Analysis has been made optional for all except the Chemical Engineers and the course 2E in General Chemistry has been increased from a four to a five hour course. The students will thus obtain in their freshmen year a more detailed study of chemical reactions and will be relieved of the work in the sophomore year. As an offset to the decreased amount of time given in Chemistry, course 1 in Chemical Engineering has been increased from a two to a three hour course to cover the general study of the chemistry of building materials. These changes will go into effect immediately and it is hoped will result in a more satisfactory balance of work in the engineering courses.

PROPOSED CHANGE IN E. E. COURSES.

The question of altering Course II in Electrical Engineering so as to include in it the study of both Direct and Alternating

Digitized by Google

The Ann Arbor Savings Bank

ANN ARBOR, MICHIGAN

Capital, $300,000 Surplus and Profits, $140,000

Resources, over $3,000,000

A General Banking Business Transacted

LUFKIN

Measuring Tapes and Rules

could not have lead the field in spite of all competition for a quarter of a century without possessing sterling quality. They could not lead the field today if they were not recognized as THE BEST—ABSOLUTELY. When you buy follow the SOUND JUDGMENT OF EXPERIENCE.

CATALOG ON REQUEST

Saginaw, Mich. THE LUFKIN RULE CO. *New York*

THE ANN ARBOR PRESS

OFFICIAL PRINTERS TO

The University of Michigan

And Its Student Publications

We print anything, from your name on a card to a book

Printers of this magazine

Press Building

Telephone No. 1 Ann Arbor, Michigan

Digitized by Google

Currents, has been considered by the faculty and the change will probably sooner or later be adopted.

At present, Course II, which begins the study of Electrical Engineering, is devoted entirely to Direct Currents and Course III, following it, to Alternating Currents. The two subjects, however, are so nearly related as to make impractical the consideration of one without the other. To bring these together, it is proposed to make Course II similar to Electrical Engineering I, as required by all Engineers except Civils and Electricals, and cover both Direct and Alternating Current Machinery. Course III would then be a more advanced treatment of the same.

The Electrical Engineering department will continue this year the practice inaugurated so successfully in the second semester of last year, of offering some practical courses in electrical work open for election by sophomores only. These courses are under the direction of Professor Higbie, who conceived them, and they promise to increase very greatly the interest of the students and the effectiveness and practical value of their efforts. Two courses are offered, as follows:

E. E. 1a—Practical Management of Electrical Machinery.

E. E. 1b—Electrical Construction.

The courses cover laboratory work only, and are in no sense theoretical. It is intended that they should precede the work in electrical physics and accompany the work in mathematics, to give the student some basis of practical experience for his work in electrical measurements and calculations, to sustain and develop his interest and enthusiasm for electrical work during the tedious and discouraging experience of acquiring the fundamental mathematics and other preparatory knowledge, and to familiarize him with the construction and manipulation of the equipment used in his profession, before he enters the technical courses of the Junior and Senior year. In this way he works at higher efficiency and speed during the first two years than he otherwise would, and will be enabled to get much more of value out of his junior and senior year than formerly. The plan seems to be working as conceived as far as we are able to judge at present. About half of the electrical engineering sophomores elected these courses the first semester they were offered.

ENGINEERING MECHANICS.

Professor G. W. Patterson, Professor of Electrical Engineering has been detailed by the Dean to have charge of the Department of Engineering Mechanics for the year 1914-1915. Lack of funds has prevented the Regents from obtaining a new outside man big enough to fill the position and it was necessary for Professor Decker, who headed the department last year, to resume the teaching of Civil Engineering Courses. Professor Patterson will devote a large share of his time to the endeavor to make the Engineering Mechanics courses satisfactory to faculty and students alike.

A new text-book, "Maurer's Technical Mechanics," is being used this semester in Engineering Mechanics I and will be used, commencing next semester, in E. M. III as well. This text, written by the Professor of Mechanics at Wisconsin, has been off the press only six months, yet has already been adopted by many engineering schols in the United States. In the opinion of the Mechanics faculty here, it is the best text-book on the subject yet written and is supplying a long felt need.

DRAWING.

Descriptive Geometry or Drawing 4 has for this year's Freshmen an entirely different aspect to what it has presented to former "Yearlings," as the subject matter has been divided into two parts. A two hour course given the First Semester covers over half of the point, line and plane propositions. A second two hour course in the Second Semester finishes these and treats the development and intersections of surfaces.

In each of these courses, the work consists of two lectures of one hour each and

Digitized by Google

Rentschler's Studio

Portrait Photographer

319 E. HURON ST. PHONE 961 M

Have YOU Dined in this New Kind of Tea Room?

Take either Elevator to Second Floor

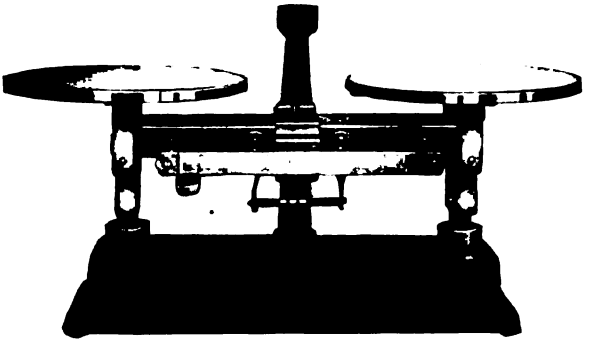
Mack & Co

CITY LAUNDRY

Work Promptly and Neatly Done
SILK SHIRTS A SPECIALTY

THOS. ROWE, Prop.

Phone 457 M 406 Detroit Street



Laboratory Supplies

Manufactured and Imported by

EBERBACH & SON CO.

Agate Bearing Balance, No. 310
List Price, $6.00

Catalogues Furnished on Request

Digitized by Google

one drawing period of three hours. For the drawing periods the Freshman Class is divided into twenty sections, and the lectures are given to two sections at a time in Room 411. This room has been remodeled and re-arranged and belongs to the Drawing Department, except for the immemorial M. E. I. lecture on Wednesdays at eleven o'clock. The Descriptive Geometry Lectures are given by Professor Gouldin, Assistant Professor Finch and Mr. Taughe, who explain and demonstrate the propositions by means of models. The taking of notes is obviated by having the lecture follow close to the order of the text-book, so that the student may devote all his attention to the lecture. Some quizzing is done in lectures and some during the three hour drawing period, much of the mechanical drawing and plate making formerly in the course having been omitted. One hour a week of outside work is utilized in the solving of assigned problems.

The alteration is expected to make Descriptive Geometry a fair amount of work for four hours credit. It has been found in the past that students were neglecting other work to ensure a passing grade in Drawing 4, rather than chance having to put in the required thirteen hours a week a second time. Under the new arrangement, a student failing to pass in either two hour course will have only half the work to go over again. The net result of the change will be the accomplishment of three things: the teaching of Descriptive Geometry in a way more profitable and more attractive to the student, a reduction in the percentage of failures, and a material lessening of the consequences of a failure in the old Drawing 4.

The Free-Hand Drawing Courses are this year being given directly under the control of the Architectural Department. These courses, from Drawing 21 on, are required of Architects and have always been modeled more or less according to the ideas and requirements of the Architectural Department. The Instructor in charge of the courses, Mr. Everett, who has been a member of the Engineering Department Staff, has been transferred to the Architectural Department and the courses, while open to Engineers, will be primarily Architectural.

SHOP.

To fit in with the change made in Descriptive Geometry, Shop I has been divided into two two hour courses, the one Wood Shop, the other Forge Shop. The student will hereafter carry one the first semester and the other the second semester, instead of both together as formerly. It is expected that the carrying of this work throughout the year will improve the physical dexterity of the Freshmen more than the crowding of it all into one semester.

ARCHITECTURE.

The following changes have been recommended in the Department of Architecture:

Courses I, II, III and the Special course are hereafter to be known as Programs I, II, II and IV, respectively, in Architecture.

Four months experience will be required in the first three programs instead of the present requirement of one summer's experience for programs I and III, and two summers for program II. (Four hours credit.) The present summer school requirement for programs I and III will be discontinued.

Architecture 2, a new two hour course in architectural drawing, shall be required of all Architectural students.

The credit of a number of Architectural courses will be changed as follows:

Architecture 4 from 2 to 3 hours.
Architecture 5 and 6 from 3 to 4 hours.
Architecture 7 and 8 from 4 to 5 hours respectively, to 6 hours.
Architecture 9 from 5 to 8 hours.
Architecture 22 from 2 to 3 hours.
Architecture 5a 5b, 6a and 6b shall each carry 2 hours credit.
Architecture 23 and 26, each 4 hours, will be given as 2 hour courses.

A 2 hour course in English will be required in Programs I, II and III, in place of English 1a.

Digitized by Google

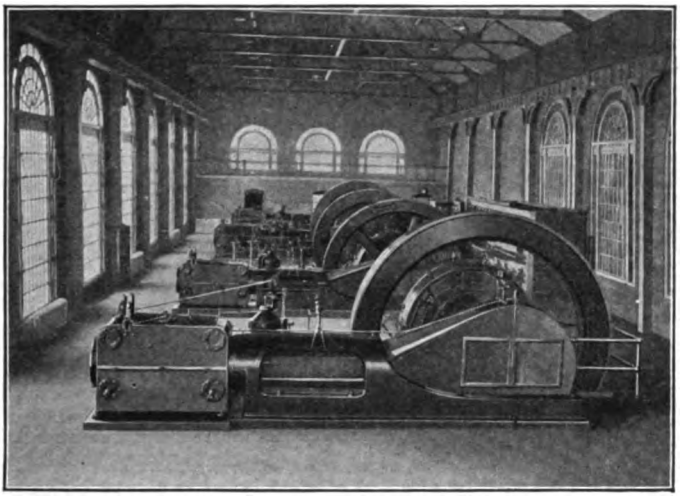
FIVE MILLION HORSE POWER

in Corliss Engines and

Four Hundred Thousand Horse Power

in Gas Engines—built by

Allis-Chalmers Mfg. Co.



ALLIS-CHALMERS CORLISS ENGINES

ALSO BUILDERS OF

Blowing Engines	Air Compressers
Oil Engines	Condensers
Steam Turbines	Hydraulic Turbines
Generators	Motors
Mining Mchy.	Flour Mill Mchy.
Pumping Engines	Saw Mill Mchy.

MAIN OFFICE AND WORKS

MILWAUKEE, WIS.

Digitized by Google

In modern languages 14 instead of 16 hours will be required.

Economics 32 (3 hours), Business Administration, will be required in Programs I and II.

Engineering Mechanics 11 and 12, 4 and 2 hours respectively, given by a member of the Department of Architecture for the students of Program II, Architectural Mechanics, Architecture 19 and 20 respectively.

In Program I, Chemistry 2 and 2a will no longer be required.

In Program II, Physics 2, E. E. 7a, Geology 1 and Law 1 are no longer to be required. An additional 3 hour course in Fine Arts is to be required.

In Program III, Architecture 7 and E. E. 1 are not to be required.

In this Program Surveying 4 (2 hours), Chemical Engineering 1 (3 hours), E. E. 7a (1 hour), Building Details (Arch. 25, 2 hours), will be required, and Chem. 2E (5 hours), is to be required in place of Chem. 2 and 2a (4 hours).

A certificate of proficiency is to be given special students who satisfactorily complete the work required in Program IV.

Drawing 4a will hereafter be a 3 hour course (now 4 hours).

No Summer Session will be conducted in the future.

CHANGE IN MATH. IV.

Beginning next semester Math. IV will be offered in two installments. It will be possible to earn three of the five hours credit the second semester of the Sophomore year and the other two hours the first semester of the Junior year. This applies particularly to Civils, whose schedules have been arranged accordingly. Moreover, Chemical Engineers will not have to take the two hour course, which treats differential equations.

NEW LATHE IN THE ENGINEERING SHOPS.

The Harkness Flat Turret Lathe, loaned to the Engineering Shops by Jones and Lamson, Springfield, Vt., is now in place and ready for use. This lathe, which costs around three thousand dollars, represents the life work of one man, James Harkness, and contains twenty-two patented features. As a machine tool it represents the highest degree of perfection yet attained and has brought into existance what might well be called a new profession. Machinists who have become expert in the turning out of work with this lathe are no longer plain "machinists" but "J. & L. Operators" and as such are much in demand.

The new lathe was obtained through the efforts of Michigan Alumni with the Packard Automobile Company, a large user of J. & L. lathes, and credit is due them for showing true Alumni spirit. It will be used principally for demonstration purposes in connection with Machine Shop Courses, and more especially in the new Scientific Shop Management Course offered for the first time this semester.

IMPROVEMENTS IN AUTOMOBILE LABORATORY

The new Diehl Dynamometer for automobile testing has been installed in the Mechanical Laboratory. It is of the design and equipment of the dynamometer in use in the New York Automobile Club and in Detroit Automobile factories and has a speed range of 500 R. P. M. to 2500 R. P. M. and a capacity of 90 H. P.

In connection with the dynamometer, a special water cooling apparatus was designed in the Laboratory here and also a fan blower which gives an air draft corresponding to actual road conditions. There has also been installed an outfit designed to run as a motor for starting gas engines under test and for measuring friction horsepower or horse-power consumption for any units at different speeds. A series of tracks has been laid out so that later a chassis may be backed in and complete tests run on a car by attaching silent chains to car wheels and drums on the dynamometer.

Course M. E. 33 in advanced automobile engineering is being offered this semester to students who have had M. E. 29 and 32. This course has been established for the

Digitized by Google

The Wickes Vertical Water-Tube Boiler

Very high thermal efficiency is obtained from this boiler and setting, because:—

1st—High furnace temperature results from Dutch oven.

2nd—Gases entirely surround and closely scrub heating surface from entrance to release.

3rd—The gases cannot leave the heating surface. There is no possible chance for short-circuiting.

4th—Boiler heating surface absorbs the heat—empty pockets in setting lose heat. There are no empty pockets in this boiler.

5th—The steel-cased settings are always tight. No cracked, warped, leaky, defective and unsightly settings exist with this setting.

6th—A steel-cased setting is a simple and sure cure for air infiltration losses. The largest preventable losses we have to contend with in boiler efficiency are excess air losses.

7th—A very long gas travel—hence long contact with heating surface is provided—hence heat absorption is assured.

The "**WICKES**" boilers are boilers that engineers and business men are, more and more, not merely thinking about and considering—but, **Purchasing**—for good and *profitable* reasons!

Let us send you intensely vital reasons and facts—they will interest you.

Ask for Full Description—Sent Free.

The Wickes Boiler Company

Main Office and Works, SAGINAW, MICH. *Sales offices in principal cities*

Murphy Automatic Smokeless Furnaces

Power Plants

that are equipped with Murphy Furnaces are operating at lower cost than others, because although getting more power they are

BURNING CHEAPER FUEL

and Saving in Many Ways

Murphy Furnaces are adaptable to any kind and any size of boiler—are automatic in all their functions—handle efficiently heavy overloads with minimum attention — and are practically smokeless

The Murphy Catalog has started many a power plant toward big savings. Get your copy today

Murphy Iron Works Detroit-Michigan

178 **New York** **Chicago** **Buffalo**

Digitized by Google

purpose of doing research work, the results of which will be published, and it represents the first attempt made in our Laboratory to lead the profession in engineering work along automobile lines.

Professor Fishleigh has been placed on the Research Committee of the Society of Automobile Engineers, which has the general direction of all research work conducted by the society.

ON THE CAMPUS

The following table shows the number of of hours of credit with which the 1914 Senior Engineers graduated:

42	Civils averaged	147 hours
55	Mechanicals averaged ..	145.5 hours
37	Electricals averaged	145.3 hours
32	Chemicals averaged	144 hours
4	Marines averaged	144 hours
8	Architects averaged	146.9 hours

Only eighteen out of a total of one hundred seventy-eight graduates had 140 hours, the minimum required number. Fourteen had 141 hours, twenty-one had 142 hours, while twenty-four men, half of whom were Civils, averaged 158.2 hours. The average for all the seniors was 145.58 hours.

For many years, about fifty per cent of the students of the Engineering Department came through with clear records each semester. A decided increase, however, set in three years ago and has continued, reaching its maximum last semester when sixty per cent of all the Engineers had neither conditions or flunks.

Advocates of the Mentor Group System can probably see in this increase the fulfillment of their expectations and the justification of the system as a necessary part of the department. We may also assume, however, that we have had a better class of students and better teaching. Both these things may have had their effect but the consensus of opinion is that the bringing of the student into intimate contact with at least one member of the faculty, enabling him to keep tab on this work throughout the semester and to receive warnings and friendly advice, has been the predominating factor in increasing the efficiency of the department.

In excavating for the foundations of the new Science Building, it was necessary to tear up a section of the concrete tunnel which housed the electric light cables and steam pipes supplying the Hill Auditorium. This tunnel, high enough for a tall man to walk through upright and as wide, with walls nine inches thick, was situated on the line of the west foundations of the new building, and will not be rebuilt in its previous form. Instead, the pipes and cables will be carried through the basement of the Science Building, the Auditorium Tunnel serving that building with heat and electricity and the Science Building basement serving as a section of the Auditorium tunnel.

Electricity for the Hill Auditorium and the new Science Building will be brought from the power plant at 2300 volts to a point near the Southwest corner of the Science Building. A pit is to be sunk there and transformers installed which will step down the current to 230 volts. This, in the course of time, will effect a considerable saving of current.

SUMMER SCHOOL BASEBALL CHAMPIONSHIP WON BY ENGINEERS.

The championship of the 1914 Summer Session League was annexed by the team representing the engineering department. This team, under the guidance of "Tommy" Hughitt, won seven out of their nine games. Hughitt, Sisler, Stewart and Eaton, with Buck Wheat as pitcher, were the engineers picked for the all-campus team which defeated the city Independents 5-1, on Ann Arbor's "Big Day." In this game Hughitt secured a homer and three singles out of four times at bat, while Stewart chalked up a round trip, a double and a single out of a like number of trips to the plate.

Digitized by Google

Styles for Fall and Winter

You'll find we don't limit you to a few patterns here.
We have the largest assortment in the city awaiting your inspection.

G. H. WILD CO.

LEADING MERCHANT TAILORS STATE STREET

WE ARE THE ONLY

Students' Supply Store

Eng. Wants Drawing Instruments Shop Tools

L. C. SCHLEEDE

1111 S. University Ave., opp. Engineering Bldg. Phone 1160 R

Furnishings to Varsity Men

BALMACAANS RAINCOATS
SWEATERS HOSIERY GLOVES

VARSITY TOGGERY SHOP

1107 S. University Ave. Phone 1160 L

University Ave. Pharmacy

GOULDING & WIKEL

Everything for the Engineer—Drawing Instruments and Drawing Supplies

Martha Washington Candy and Belle Meade Sweets
Drugs Stationery Cigars and Toilet Articles

"The New Place," cor. S. University and Church Phone 416

Digitized by Google

ERRATA

In Article on "Hingeless Arch" in May issue by F. A. Steiger, make following corrections:

Page 9, line 9, for Ms/EI, read $\Sigma Ms/EI$.
Page 9, line 10, for Msy/EI, read $\Sigma Msy/EI$.
Page 9, line 11, for Msx/EI, read $\Sigma Msx/EI$.
Page 9, line 19, for inertia of, read inertia at center of.
Page 9, line 20, for Ms/EI, read $\Sigma Ms/EI$.
Page 9 line 23, for Msy/EI, read $\Sigma Msy/EI$
Page 9, line 27, for Msx/EI, read $\Sigma Msx/EI$
Page 10, line 34, for the same ordinates, read the same center ordinate.
Page 10, line 36, for collect, read correct.
Page 11, line 2, for Fig. 3, read Fig. III.
Page 11, line 4, for to substitute an, read to subdivide an.
Page 13, line 41, for (equation), read therefore (equation).
Page 13, line 43, for (equation), read (equation) (4).
Page 14, line 1, for $AO = 38$, read $\Sigma AO = 38$.
Page 14, line 1, for $Po = 38.2912$, read $\Sigma PO = 38.2912$.
Page 14, line 38, for D (Fig. 2), read D_1 (Fig. II).
Page 15, line 30, for at the load point, read at the load points.
Page 16, line 1, for C_1A_1G, C_1 equals, read C_1A_1G, C_1G equals.
Page 17, line 14, for (formula) (2), read (formula) (5).
Page 18, line 19, for apply in equation (1), read apply in equation (4).
Page 19, line 1, for (2), we get, read (5), we get.

In "Practical Applications of Logarithmic Paper" by W. F. Verner, make the following corrections:

On page 23, line 12, for "the product of 'P' and 'IV' ", read "the product of 'P' and 'I' ".

On page 27, in place of the equation "$W/S = \ldots$.", read "$W/V = \ldots$.".

On page 28, the equation should read as follows:

$$d = .0048 \sqrt[5]{\frac{I(h + h^1)h}{P}}$$

On page 29 the equation for "d" should read as follows:

$$d = .0048 \sqrt[5]{\frac{1{,}000(1{,}000{,}000)^2}{P}}$$

On page 20, lines 14, 15, 25, 26, 27, substitute signs of equality for all minus signs.

Digitized by Google

THE MICHIGAN TECHNIC

VOL. XXVII
NUMBER 3

ANN ARBOR, MICH.
DECEMBER, 1914

PRICE 25c
SUB. YEAR, $1.00

TABLE OF CONTENTS

Frontispiece—Hon. Lawton T. Hemans.

The New Engineering Society 175

Critical Review of the Different Phases of the Evolution and the History of the Internal Combustion Engine. *A. F. Greiner* 178

Inventive Genius and Commercialism. *L. J. Watson* 218

An Approximate Numerical Solution of Differential Equations in Two Variables. *Prof. T. R. Running* 221

Report of Committee on Combined Course with Albion College 229

Address Before Freshman Class. *Hon. Lawton T. Hemans* 231

Spring Trip of Mechanical Engineers 233

Editorials 234

Departmental Notes 238

- Research.
- Michigan Men in the Press.
- New Books by Michigan Men.
- Departmental Classes.
- Societies.
- News Notes.

Alumni Notes 249

Transitory Slants. *Harold R. Schradski* 256

Errata in October Issue 260

Digitized by Google

Digitized by Google

VOL. XXVII DECEMBER, 1914 No. 3

THE MICHIGAN TECHNIC

OFFICIAL ORGAN OF THE

ENGINEERING DEPARTMENT

PUBLISHED QUARTERLY

BY THE

ENGINEERING SOCIETY

(INCORPORATED)

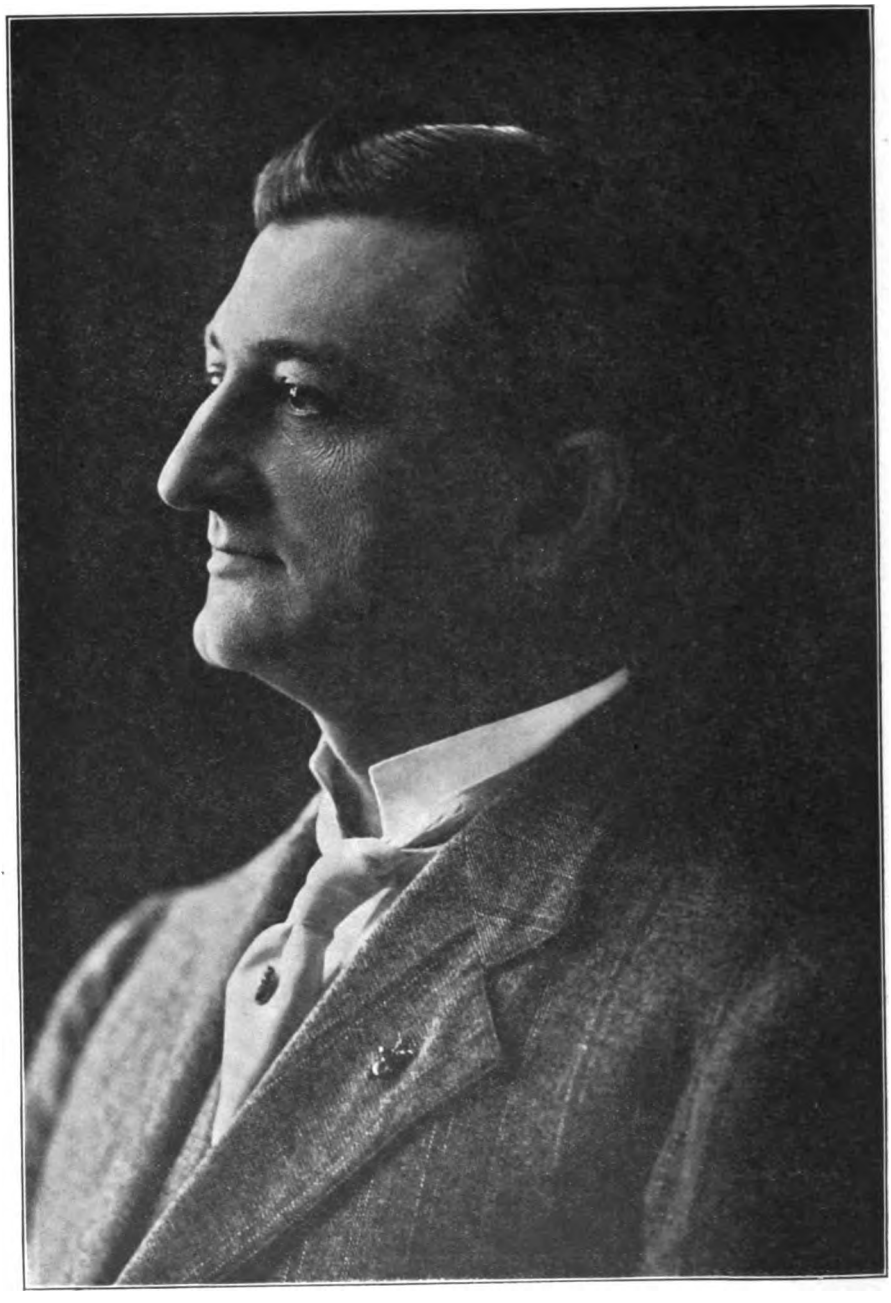
UNIVERSITY OF MICHIGAN

TWO THOUSAND COPIES

PRICE 25 CENTS

[SUBSCRIPTION, $1.00 PER YEAR

Digitized by Google



HON. LAWTON T. HEMANS.

Digitized by Google

THE MICHIGAN TECHNIC

VOLUME XXVII NUMBER 3

PUBLISHED BY THE

UNIVERSITY OF MICHIGAN ENGINEERING SOCIETY

THE NEW ENGINEERING SOCIETY

The last two issues of the MICHIGAN TECHNIC have referred to the New Engineering Society at different times, without giving any definite reasons for calling it the "new" Engineering Society. Up to the present time, matters have not stood so that a complete detailed description could be given. It is the purpose of this short article to attempt to clearly show just what the Engineering Society is today, what it stands for, and what advantages may accrue from membership in the organization.

In order to partially explain the causes for the reorganization, it may be well to go back into the earlier history of the Society. It was founded primarily to meet the needs of the students in the Engineering Department for a general meeting place, and the privileges of a reading and studying room. Lectures were also arranged for their benefit, being given by prominent men of the outside world. Later on, the Society took onto itself the responsibility of publishing a magazine, the MICHIGAN TECHNIC. This was founded in 1886, a few years after the founding of the Society. For a number of years the Society and TECHNIC enjoyed success, as the department was not so large as to dwarf the possibilities and advantages of such an organization and combination. Papers were given by student members, and issued in the form of transactions, and later on in the MICHIGAN TECHNIC. It is an interesting fact that a number of the papers written by the early graduates of the University of Michigan, and printed for the first time in the MICHIGAN TECHNIC, were later in great demand on account of their value to the engineering world. Some of them were reprinted on account of the great demand for the articles.

Matters progressed in a successful way until, for some unknown reason, interest seemed to fall off in the Society, and, naturally, in the MICHIGAN TECHNIC. For some years, things dragged on thus, with no apparent direct cause for the falling off in the interest, so essential to the proper maintenance of the functions of the Engineering Society. As is well known to the graduates of the past few years, the Engineering Society and the TECHNIC have had hard sledding to make their way, and have been at times, dormant. Occasionally an exceptionally energetic board would get into charge, and things would boom for a short time, only to die out with the passing in of a new and less active board.

Matters finally reached the stage where something definite and positive had to be done, and done with dispatch. A committee was appointed to investigate the reasons for the success of similar organizations in other insti-

Digitized by Google

tutions, and to report on a scheme suited to the proper reorganization of the Society. This committee took the better part of a year in this work of investigation. It communicated with societies in other schools; consulted with prominent faculty members, many of whom had had an active part in the work of the early Society; and, most important of all, made a careful study of the conditions existing in the Engineering Department. As a result of these thorough investigations, a new plan was drawn up by the committee, approved by the faculty, and ratified by the Engineering Society.

Plan of Organization.

The basis of this plan was laid upon the uniting of the interests of the separate Engineering groups into one general society, providing at the same time means for maintaining the interest in each of the Engineering groups. It was found that, in the first place, the Engineering Department had grown so much faster than had the Society that it had lost track of it, and, in the second place, the Engineering groups had been segregated to such an extent that intercommunication was almost futile. None of the Civils took Mechanical courses, the Marines and the Chemicals never saw each other, the Electricals were herded off in a corner of the basement by themselves, and, as a consequence, general meetings of the Society had nothing in common for any more than one group, to which that particular meeting might furnish interest.

Accordingly, steps were taken to organize sub-societies in each group, with the result that, today, there are four branches: the Student branch of the American Institute of Electrical Engineers; the Student branch of the American Society of Mechanical Engineers; the local branch of Chemical Engineers; and the local branch of Civil Engineers. Owing to the fact that there are no student branches in the National Chemical and Civil Engineering Societies, the branches formed are strictly local. There is very live possibility of the organization of a student branch of the Society of Automobile Engineers in the near future.

The next step was to unite the separate interests of these sub-societies into a General Society, which was to represent the school. Accordingly the head officers of each of the sub-societies formed a board of control at the head of the General Society, and one of the members of the board of control was elected Chairman. In this way the interests of each of the sub-societies could be closely kept in touch with, by means of the head officer of the sub-society, and the policies of the General Society were but a combination of those of the sub-societies, as expressed through their head officers. Each society, of course, had its separate organization with its officers, time of meetings, programs, etc., so that it was, in reality, a complete society in itself.

Membership.

The membership in the societies was arranged as follows. In the branches of the National Societies, the regular dues of the National organization were paid to the proper officer of that society, and in addition a certain sum was paid into the treasury for maintaining the General Society, the Society rooms and the Michigan Technic, subscriptions to which were included in this sum. In the other branches the dues were set by the society itself, with the regulation that a certain sum, as before, be paid over to the General Society. As some of the

Digitized by Google

branches could not include Freshmen in their membership, a special arrangement was made whereby they could be admitted to the roll of the General Society by payment of one dollar, and had, then, the privilege of attending the meeting of the particular society in which they were interested, without actually being active members.

Results.

The outcome of the reorganization has not been capable of accurate measurement as yet, on account of the delay and difficulty connected in getting the old order of things broken up, and the slowness in getting the new organization under way. Several things have already indicated that the new plan is a satisfactory one, however, as there is being shown an interest in the Society never taken before within the memory of the oldest P-G student in the Department. The present members are showing great interest, and are planning active campaigns to increase the membership of the sub-societies, and the General Society.

Digitized by Google

CRITICAL REVIEW OF DIFFERENT PHASES OF THE EVOLUTION AND THE HISTORY OF THE INTERNAL COMBUSTION ENGINE

A. F. GREINER

The internal combustion engine is now in the 6th decade of its development. During this time constructive engineering and scientific research have increased the economy and output of this, our oldest heat engine, to a truly wonderful degree, both in the improvement of the materials of construction and in the understanding of the working cycle. The fuel consumption per B. H. P. hr. has been decreased from 106 cu. ft. of illuminating gas to 14 cu. ft., the thermal efficiency has increased proportionally from 4% to approximately 30% and the specific capacity has been increased tenfold. This is the case not only when operating with coal-gas proper, but all combustible gases, irrespective of impurities or of heat value, are now capable of economical use as fuel for internal combustion engines. Where such gases are not available as the main- or by-product of the industry, the gas can be produced from solid fuel in the same economical manner in which it is used in the engine.

So out of the original small motors highly satisfactory prime movers were developed for the large industries, which even now are built in 500 H. P. units, and are distributed all over the world in more than 800,000 installations and with a combined output exclusive of automobile engines of much over eight million H. P. (Refer. Bulletin 55 Bureau of Mines 1913.)

The old competition between gas and steam power still goes on, enlivened continually by the increasing successes of the internal combustion engine. Over-zealous followers of Otto and Diesel now as in 1860 prophesy a rapidly approaching end for the great creation of James Watt.

After its rapid development, the internal combustion engine has attained and energetically maintained its purpose—the supply of power to the industries. At this time, a critical review of the different phases of its evolution and history will furnish the internal combustion engine designer with valuable information. For him, the unsuccessful experiments and projects of others will serve as salutary instruction. They will show him the ways and means by which the capacity and economy of the engine were increased step by step, and they point out the direction in which he may expect further development.

In order to make such a practical application possible, the history of the engine should however not be drawn entirely from patent specifications and general publications concerning successful engines. It must deal thoroughly with the manufacture and operation of the engines and should include not only the final results but should also take into consideration everything done from its first conception in the mind of the inventor to the final successful test. For the proverb, "Probleren geht über studieren," (Experiment is more valuable than study) is especially true for the gas engine designer.

Digitized by Google

Numerous inventions—among them some whose claims of success had been proven by computations carried to the fifth decimal place,—failed completely on the testing block. Sometimes the results obtained were such that the original ideas of the inventor could hardly be recognized. For instance, Otto started out with the four-cycle compression engine; he digressed to the atmospheric engine, and after fifteen years he resumed work on his four-cycle engine which is even today the most successful type. Diesel intended to build an isothermal combustion coal-dust engine. What he arrived at was an oil engine with a three-fold increase in temperature during combustion. On the other hand practical experiments often obtain successful results even if the fundamental theory would indicate the very opposite. For instance, does not the injection of water into the cylinder, as it was done in the Banki engine, appear doubtlessly uneconomical from a thermodynamical stand point? And yet Prof. Banki obtained by this simple means a very remarkable reduction in fuel consumption.

It is a rule in such cases where the results really obtained are so far removed from those originally desired, that during the experimental period a great deal of research and constructive work is wasted, which often has, or at least should have an instructive influence on others. But usually, history has nothing to say about this preparatory and inventive work, for the independently creating designer makes a secret of his unfinished and unsuccessful attempts, unless unusual causes like patent suits, etc., force him to make them public. So it happens that tedious and expensive experiments, the impracticability of which has long since been established, are continually repeated by others, causing an unnecessary waste of many thousands of dollars.

Such experiments are a fruitless work which even a perfect history of the internal combustion engine could not completely do away with. The following review of the most important working cycles and forms of development of this heat engine will at least show in outline what has already been done in this great field. Its history falls into two periods.

I. Period of invention and speculation.
II. Period of development and application.

I. PERIOD OF INVENTION AND SPECULATION. (1678-1860.)

Vacuum Gun-Powder Pump.
HAUTEFEUILLE, 1678.

Through the explosion of gun-powder in a closed chamber provided with valves and the subsequent cooling of the gases of combustion, a vacuum is created which is used for the drawing of water.

Vacuum Gun-Powder Engine.
HUYGHENS, 1680.

By the creation of a vacuum in the same manner as Hautefeuille, however, carried on in an engine cylinder, the atmospheric pressure is used for the operation of a piston.

Digitized by Google

Directly Working Gun-Powder Pump.
HAUTEFEUILLE, 1682.

The pressure resulting from the explosion of gun-powder is used for lifting a water column.

Vacuum Gun-Powder Engine.
PAPIN, 1688.

Contructive work and practical tests according to the ideas advanced by Huyghens.

Gas Turbine.
JOHN BARBER, 1791.

Gases produced from solid or liquid fuels and mixed in a special chamber with air and a little water are ignited and the resulting impulse is to be utilized for the operation of a turbine wheel.

Oil Engine.
ROBERT STREET, 1794.

Liquid fuel is evaporated in a cylinder and mixed with air taken in during the first half of the stroke. The mixture then is ignited by a continuously burning ignition flame at the middle of the stroke and the piston is driven outward by the gases.

Double Acting Illuminating-Gas Engine.
LEBON, 1801.

Gas and air are pumped into a mixing receiver, are then taken over into the double acting working cylinder and electrically ignited.

Vacuum Illuminating-Gas Engine.
SAMUEL BROWN, 1823.

In a working cylinder provided with a water jacket a vacuum is created by relieving the combustion pressure of the remaining gases by cooling, so that the atmospheric pressure can be used as a driving means. (Practically applied.)

Double Acting Explosion Engine.
WELLMANN WRIGHT, 1833.

Engine with two charging pumps and a centrifugal, quality regulating governor. Working cylinders are water jacketed. Ignition occurs at the dead center by means of an ignition flame. (Practically applied.)

Explosion Engine with Compression.
WILLIAM BARNETT, 1838.

Gases and air are separately subjected to compression by the charging pumps and after being mixed in the cylinder are further compressed. Ignition occurs at the dead point by means of a glowing sponge of platinum or by a flame valve.

Digitized by Google

Condensation Gas Engine.
JAMES JOHNSON, 1841.

The piston is driven outward by the explosion of a hydrogen-oxygen mixture. A vacuum is created under the piston by the condensation of the steam produced.

Hot Tube Gas Engine.
DRAKE, 1842.

Illuminating gas engine with a plunger piston, suction during the first half stroke. Quality regulation by a centrifugal governor. The cast-iron hot tube is heated by compressed gases and the ignition channel is laid bare by the piston at the middle of the stroke. Later petroleum was used. Practically applied. Engine exhibited in Philadelphia in 1847, had an output of 20 H. P. at 103 lbs./in^2 explosion pressure and a M. E. P. of 38 lbs./in^2 and a speed of 60 R. P. M.

Hydrogen Gas Engine.
CHRISTIAN REITHMANN, 1852.

A mixture of air and hydrogen is compressed by means of a special pump to a pressure of 2 to 8 atmospheres, electrically ignited and the combustion gases are expanded in a cylinder. (Practically applied, was in operation in Munich until 1858 and then remodeled for illuminating gas.)

Atmospheric Free Piston Engine.
BARSANTI AND MATTEUCCI, 1854.

The explosion pressure of an electrically ignited gas mixture drives a free piston upward in a high vertical cylinder. In this way very complete expansion occurs and through the cooling of the gases a vacuum is created under the piston. The piston driven down by the atmospheric pressure operates the crankshaft by means of a rack and pinion. A second flat piston moved by this shaft controls the inlet and outlet channels of the compression chamber and draws in the fresh mixture. (Built in 1857 by John Cocherill in Seraing.)

Gas Engine with Compression.
DEGRAND, 1858.

It is proposed to compress the mixture in the working cylinder itself instead of in special charging pumps as heretofore.

For References, see: Güldner, Schöttler, D. Clerk, and Donklin.

PERIOD OF DEVELOPMENT AND APPLICATION.
(1860 to Date.)

(A) Gas Engines.
- (a) Without Compression.
  - a′ Direct Acting.
    1. Lenoir.
    2. Hugon.
    3. Bisschop.

Digitized by Google

b′ Atmospheric (free-piston) engines.
1. Otto and Langen.
2. Reithmann and Aimüller.
3. Gilles.

(b) With Compression.
a′ Constant Pressure Engines.
1. Brayton.
2. Simon.
3. Diesel.

b′ Explosion Engines.
a″ Four Cycle and Multicycle.
(1) Beau de Rochas.
(2) Reithmann.
(3) Otto.
(4) Loutzky.
(5) Delamare-Debouteville.
(6) Charon.
(7) Crossley Bros.
(8) Westinghouse.
(9) Rollason-Beck.
(10) Griffin.
(11) Maschinenfabrik-Augsburg-Nürnberg (Man.).
(12) Langen and Wolf.
(13) Cockerill.
(14) Allis-Chalmers.
(15) Snow.
(16) Tod.
(17) Westinghouse.
(18) Buckeye.
(19) Mesta.

b″ Two Cycle.
(1) Merk.
(2) Wittig and Hees.
(3) Benz.
(4) Mietz and Weiss.
(5) Southall.
(6) Benier.
(7) Oechelhäusser.
(8) Körting.
(9) Hörbiger and Rogler.

(B) Gas Turbines.
(1) Armengaud and Lemate.
(2) Dr. Stolze.
(3) Holzworth.

(C) Gas Pump.
(1) Humphrey.
(2) Brown Bovery and Co.

Digitized by Google

(D) Oil Engines.
- (a) Without Compression.
  - 1. Lenoir.
  - 2. Otto and Langen.
  - 3. Hock.
- (b) With Compression.
  - a′ Constant Pressure Engines.
    - 1. Diesel.
    - 2. Augsburg-Nürnberg.
    - 3. Busch-Sulzer Brothers.
    - 4. Krupp.
    - 5. Dentz.
    - b″ Two Cycle.
      - (1) Brayton.
      - (2) Hargreaves.
      - (3) Capitaine.
      - (4) Breinnler.
      - (5) Geildner-Diesel.
      - (6) Sulzer-Diesel.
      - (7) Hesselmann-Diesel.
  - b′ Explosion Engines.
    - a″ Four Cycle.
      - (1) Daimler.
      - (2) Spiel.
      - (3) Capitaine-Grob and Co.
      - (4) Priestman.
      - (5) Hornsby-Akroyd.
      - (6) Dropp-Capitaine.
      - (7) Banki-Ganz and Co.
      - (8) Haselwander.
      - (9) de la Vergne.
    - b″ Two Cycle.
      - (1) Söhnlein.
      - (2) Güldner.
      - (3) Kablitz.
      - (4) Samson.
      - (5) Junge.
      - (6) Elmore.
      - (7) Bolinder.
  - c′ Combination Explosion Constant Pressure.
    - (1) Sabathé.
    - (2) Trinkler-Körting.

(E) Coal Dust Engine.
- (1) Wickfield.
- (2) Diesel.
- (3) Worgitsky.
- (4) Maccallum.

Digitized by Google

(A). GAS ENGINES.

(a). Gas Engines Without Compression.

Lenoir.

Early in 1860, almost 50 years after the opening of the first public Gas works, the french mechanic Lenoir arrived at a satisfactory way of using coal gas for power purposes. Lenoir constructed the first serviceable gas engine not as a far sighted inventor or a creative designer, but by means of a path cleared by others. His engine was the product of a skillful combination of well known details, the careful study of the most favorable working conditions and the fortunate overcoming of practical difficulties. The originality of the Lenoir engine was not held very highly even by the manufacturers themselves. In a paper published by M. Lefevre of Paris, in 1864, was stated, "The Lenoir engine uses the piston according to the patent of Robert Street, it is direct and double acting as Lebon's engine, it is electrically ignited as that of von Rivaz, it can be operated by hydrogen as proposed by Herskine-Hazard, and probably we would recognize Talbot's splendid ideas in the slide valve as used by Lenoir. But the Lenoir engine draws in gas and air itself without previous mixing—the latter is always dangerous and requires special pumps—and that constitutes his patent claims." This new motive power was rapidly heralded to the world by overbold and possibly unscrupulous advertising.

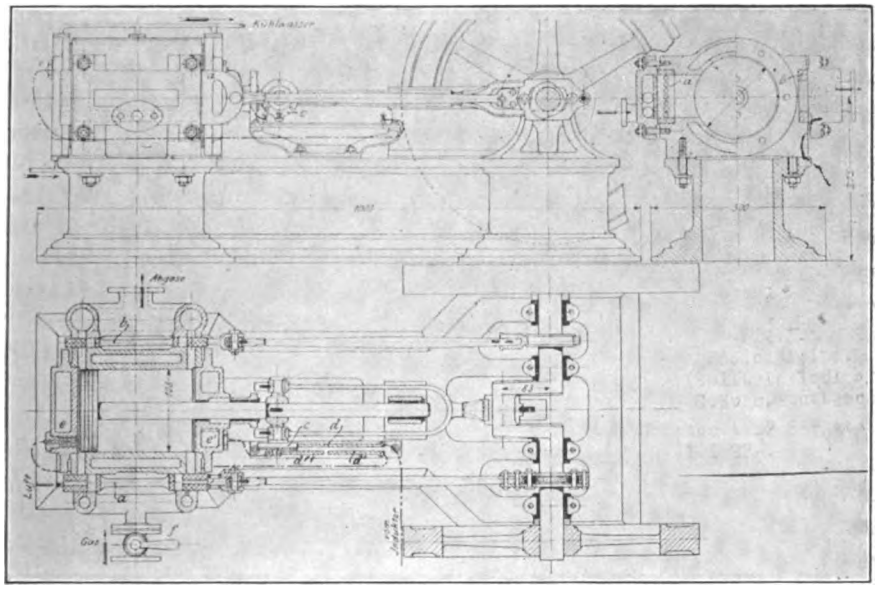
The original experimental period was evidently very short. Only eight months after procuring the French patents (Jan. 24, 1860) a 1 H. P. Lenoir engine was in public use in a Paris machine shop. Lenoir's original engine had a bore of 3″ and a 5″ stroke. It was without a waterjacket, was however double acting and was electrically ignited. A continuously sparking ignition plug located in the wall at the middle of the cylinder was laid bare by the piston at the middle of its stroke and in this way ignited the mixture in the front and back end alternately. A plain slide-valve operated by an eccentric was located on the side of the cylinder and provided for inlet and outlet. The following two experimental engines were larger and were provided with a water jacket for cooling the cylinders and cylinder heads. Still like the first engine they did not show any original ideas and were modeled after the current steam engine types.

The individual construction and arrangement of the Lenoir engine began only when its manufacture was licensed to capable firms. The construction which showed the most skilful work and served as model for many later engines was that of Marinoni, a machine manufacturer of Paris. In Germany the firm of G. Kuhn of Stuttgart, built a small experimental engine in 1861 according to the working drawings of Marinoni. The tests of this engine gave unsatisfactory results and for this reason the manufacture was discontinued. Fig. 1 shows this first and also last Lenoir engine of German construction.

In the position of the piston, as shown in the diagram, the slide valve (a) admits the mixture at the left side of the cylinder, while on the right side the slide valve (b) opens to the exhaust pipe. The inlet valve (a′) is

Digitized by Google

controlled by a cam fixed on the crank-shaft. The cam profile is followed by two rollers which are held in place by a frame of wrought iron plates. The exhaust valve (b) is operated by an ordinary eccentric. At the middle of the stroke the valve (a) cuts off the influx of the gases. Immediately after this the contact point (c) on the front end of the cross-head closes the circuit between the guides (d) and (d′), which causes a continuous spark at the plug (e), until the circuit is broken on the return stroke, when (c) leaves the guide (d′) and closes the circuit through the crankend ignition plug (e′) by making contact with (d″). The ignited mixture explodes with a pressure of about 60 to 75 lbs. per square inch. Release occurs at the dead center at a pressure of about 7 lbs./in^2. Simultaneously with the opening of the



LENOIR ENGINE, 1861.

headend exhaust valve (b), the crankend exhaust valve is closed by the same slide. After this the charging and combustion processes are repeated in the crankend in the same manner as above stated for the headend.

The speed regulation of the engine shown in the cut, as in Lenoir engines of the first few years, was obtained by adjusting the gas valve by hand. The automatic regulation of the fuel by means of a centrifugal governor was later accomplished by Marinoni after many tedious experiments. The high tension ignition current was obtained from an induction coil, the primary circuit of which was supplied with current from two large Bunsen cells. These cells required a new sulphuric or nitric acid bath every three or four days.

The cylinder walls and covers required very thorough cooling, and in most cases the cooling water was used only once. Temporarily, however,

Digitized by Google

Lenoir used the evaporating cooling system with automatic water circulation, very much as it is used today. The heat of the exhaust gases affected the exhaust valves very strongly, causing warping and much friction. At the richest mixture, which occurred at the heavy loads, the temperature at the release point was sometimes as high as 1400 degrees Fahr. and consequently friction of the exhaust valve very often increased, in spite of extravagant oiling, to such an extent that it stopped the engine. Every change in lubrication was followed by a noticeable change of speed. In the larger types water was sprayed into the cylinder just before release in order to reduce the temperature of the gases before they passed through the valve.

Lenoir engines were built as large as 12 H. P. The 100 H. P. engines, which were advertised right from the beginning existed on paper only. The same is true of the gas locomotives, motor cars and fire engines which the company recommended so heartily. The first publication concerning the new engines which were given out as early as the summer of 1860 were nothing more than promiscuous exaggerations and indulged pathetically in funeral dirges for the steam engine. Off-hand the builders and salesmen gave the gas consumption per B. H. P. hr. at from 15.9 to 17.6 cubic feet and upon this basis computed very deceptive and tempting operating costs. Steam power seemed to be entirely lost and out of date. Then came the results of tests by impartial experts and the equally important gas bills of the owners, showing a gas consumption six times as high as that promised by the builders.. The enthusiasm was at an end. As in the beginning, there had been no limit to the praise of this motor, there was now no limit to the blame. The really good features of the first gas engine were underestimated and were discarded with its bad features. Of course it was a fuel and oil eater and under varying load had an irregular and pounding movement, and the ignition was the cause of much trouble; on the other hand, however, the engine was simple in erection and operation, was always ready to start, cheaper in initial cost than a steam plant and was not subjected to governmental regulations. In small plants where the operation was not continuous or the fuel cost was not an important factor, the Lenoir engine could be used very well, and under these circumstances was superior to steam. Its operation, after the primary difficulties of construction had been overcome, was dependable. As a proof of this might be mentioned that long after the adoption of the Otto 4-cycle engine, Lenoir engines were in daily use, and even today Lenoir engines that are in a serviceable condition are occasionally found.

Test of Lenoir Engine. (Max Eyth.)

Tests made by the noted German engineer, Max Eyth, on the engine described above:—Dimensions: Bore 4.21″, stroke 6.58″.

Digitized by Google

Test No.	1	2	3	4	5	
R. P. M.	130.	105.	100.	105.	100.	
Fuel consump. per B. H. P. hr. in cu. ft.	42.5	192.5	148.	99.	102.	
B. H. P.	No load	0.25	0.46	0.6	0.7	
Gas in mixture	3.6%	5.6%	7.1%	6.8%	8.4%	Without reference to Vol. Effy.
Explosion press in lb/in². p_e	28.4lb	35.5lb	49.7lb	64.lb	71.2lb	
P_m in lb/in²				14.4lb	15.5lb	Mean pressure considering the loss due to friction
Economical Efficiency $= n_w$	0.	2.3%	3.%	4.45%	4.35%	Assumed heat value at 562 B.T.U./ cu. ft.

(1) $p_m = p_i \times n_m$ where p_i is the mean pressure from indicator card and n_m = Mech. Effy.

(2) $n_w =$ " over all effy." $= n_t \times n_g \times n_m = n_i \times n_m$, where n_t is the theoretical effy . and n_g is the card factor, and n_i = indicated effy.

During the overload test No. 5, the engine, in spite of extravagant lubrication stopped after 14 minutes' run. Fig. 2 shows indicator card of test No. 5 and Fig. 3 that of test No. 1. The noticeable drop in pressure

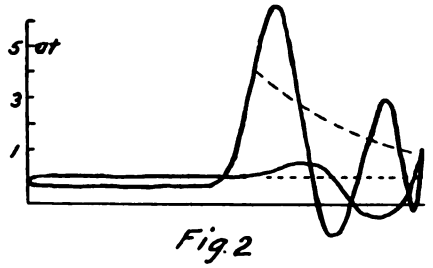


Fig. 2

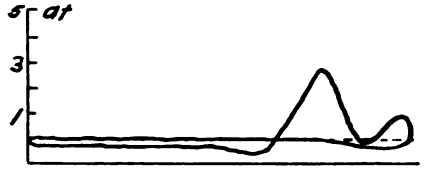


Fig. 3

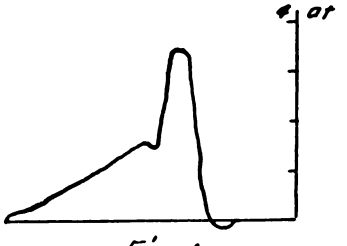


Fig. 4

between the cut-off and explosion in Fig. 3 disappears entirely in the overload diagram on account of the drop in speed and the higher initial temperature of the mixture.

Digitized by Google

The Hugon Engine.

The success of the Lenoir engine produced a host of imitators and rivals, several of whom set up a prior claim to the invention. One of the latter was Mr. Hugon, manager of the Peris Compressed Gas Co., whose original patent is dated September 11, 1858. Apparently he was the inventor of the engine which was later built and so well advertised by Lenoir. But Hugon who studied the gas engine question with great care, was not so optimistic as Lenoir and considered his solution of the problem so unsatisfactory that he did not even publish it. Furthermore, his engine had a lower fuel consumption than Lenoir's, which can be seen from the test below. The later Hugon engines differed from the Lenoir engines as follows:

1. Having the inlet and exhaust valve combined in one slide valve which allows good cooling of the ports by the incoming gases.

2. Injecting a small quantity of water into the cylinder to reduce the temperature of explosion and release.

3. Using flame ignition which gave better flame propagation than with electric ignition and therefore a higher efficiency.

Test of Hugon Engine (Made by Prof. Tresca).

Nominal Output	2 H.P.	Gas content of charge	7.50%
Bore	13 in.	Cutoff	42–45%
Stroke	12.5 in.	Explosion press p_e	41–48 lb/in²
R. P. M.	52.	Water injection	8
B. H. P.	2.07	Water injected per hr.	128 lb
Gas per H. P. hr. (without ignition flame)	86.5 cu.ft.	Heat lost in cooling water per hr. per H. P. in B.T.U.	123,000
Gas consumption for four ignition flames per hour	9.85 cu.ft.	Temp. of Exhaust gases	186°
Gas per H. P. hr. with ignition	91.25 cu.ft.	p_m	4.66 lb/in²
		n_w	5.17%
		n_m	58.0%

Assuming the lower heating value of the gas at 675 B. T. U. per cubic foot, Tresca gives a 5-hour heat balance of this engine as follows:

	B. T. U.	%
Loss to injected water	150,000	40.11
Loss in cooling water	127,000	34.19
Loss in exhaust gases	69,600	18.70
Useful work done	26,200	7.00

Hugon himself gave the amount of cooling water used at 1100 lbs. (135 gal.) and the injected water at 110 lbs. (13.5 gal.) per H. P. hr. Fig. 4-5 give indicator cards from this test.

The Bisschop Engine.

In 1871 Bisschop used the Lenoir cycle in a very original engine, the design of which was far removed from that of current steam engine practice. The engine was unique in construction and well fitted for the requirements of small shops. The firm Mignon & Rouart, of Pais, built this engine in three small sizes, .04 H. P., .08 H. P., and .33 H. P. However, larger types

Digitized by Google

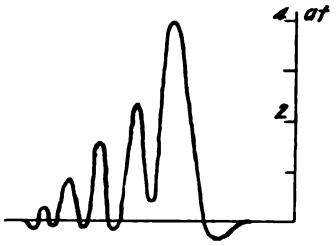


Fig. 5.

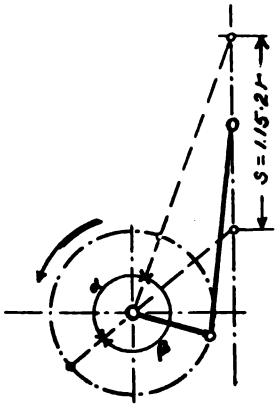


Fig. 8

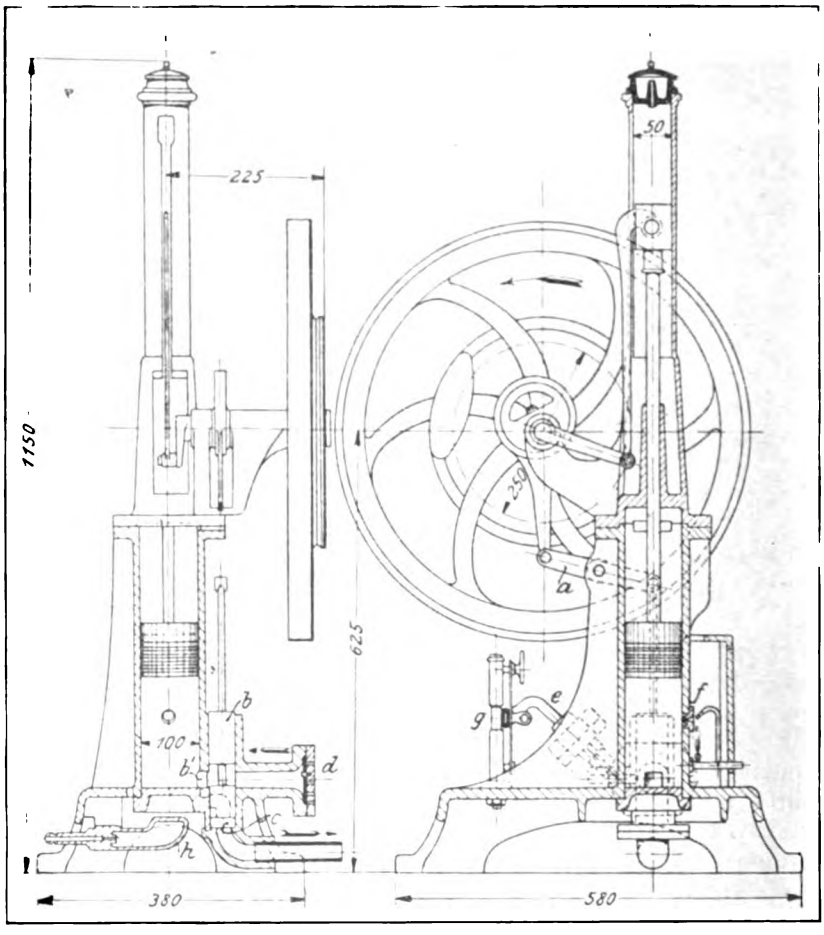
Fig 7 Set off crank of Bisschop Engine

were built by the German firm Buss, Sombart & Co., of Madgeburg. On account of the more efficient free piston engine of Otto, the distribution in Germany was very limited.

(Fig. 6). The cylinder was provided with wide cooling webs arranged logitudinally. This increased the cooling area 6 to 8 times and so water cooling was eliminated. Immediately above the cylinder, and in line with it, was placed a cylindrical crosshead guide, which was slotted on one side to give room for the curved connecting rod. The top of this guide was closed by a cap which contained a wick oiler to lubricate the crosshead. The piston had three steel rings. The working piston and the piston valve were not lubricated. An opening in the upper part of the cylinder allowed outside air to be drawn in and expelled at every revolution, and in this way helped to cool the cylinder. Intake and exhaust were controlled by the piston valve (b) which received its motion from the crank shaft by means of an eccentric and the walking-beam (a). Fig. 6 shows the piston in mid-position just before ignition. When the piston is at the bottom of the cylinder, the valve (b) has just closed the outlet (c). When the piston moves up, air is drawn in through tube (d), and simultaneously the proper proportion of gas is drawn in through the connection (e). Suction continues until midstroke, when the piston uncovers the ignition channel (f) located in the cylinder wall.

Digitized by Google

This channel or chamber is closed by means of a little trap door opening into the cylinder. At about mid-stroke, when the piston has uncovered this trap-door, it is opened by the partial vacuum in the cylinder and the flame ignites the mixture. The explosion pressure closes the trap door and drives the piston out. The ignition flame is extinguished at every explosion. Immediately below the ignition flame, there is a continuously burning lamp



BISSCHOP ENGINE.

which starts the ignition flame before the next stroke. At the ignition point the valve (b) has not quite closed the inlet chamber (b'). For this reason, special check valves are inserted in the gas and air pipes. At the end of the out-stroke the lower end of the piston valve (b) opens the exhaust port (c) through which the descending piston expels the burnt gases. The speed was regulated by hand by adjusting the pinch cock (g) in the gas tube. In the 0.5 and 1 H. P. engines made by the German firm, however, an automatic governor was used. The bunsen burner (h) under the cylinder was lighted

Digitized by Google

shortly before starting to preheat the mixture and facilitate ignition. The Bisschop engines made by the German firm had a more reliable ignition and did not require this preheating.

The offset crankshaft requires some explanation. Diagram 7 gives the ignition position in full lines and the dead center position in dotted lines. It shows that explosion occurs when the connecting rod is nearly parallel to the axis of the cylinder and almost perpendicular to the crank. In this way the normal pressure on the cross-head guide is much reduced, and the maximum piston pressure is transmitted to the crank at the instant when it produces the greatest turning moment. In such an offset crank, the stroke is greater than twice the radius of the crank. In the Bisschop engine, the stroke was 12 to 15% greater than the crank diameter. The dead center positions divide the crank pin path in two unequal parts in which angle α is less than angle β.

With direction of rotation as shown in the diagram, the larger angle β will be passed over during the upstroke and the smaller angle α during the down-stroke. Since the angular velocity of the crank is practically constant, the stroke in which the intake explosion and expansion occur is given more time than the exhaust stroke. From a thermodynamical point of view, the opposite would appear more correct. Apparently Bisschop preferred the mechanical advantages.

Results of Test of Bisschop Engine. (Made by Prof. Schöttler and Frese.) Dimensions: Stroke 11.5", bore 3.1".

No. of Test	1	2	
R. P. M.	92.	98.2	
B. H. P.	0.17	0.19	
Gas consumption in cubic ft. per hour	25.2	31.3	
Gas consumption per B. H. P. hr.	148.	165.	
Economical Efficiency. n_w	2.37%	2.43%	Assumed heat value at 561 B.T.U. per cu.ft.

See indicator cards Fig. 8.

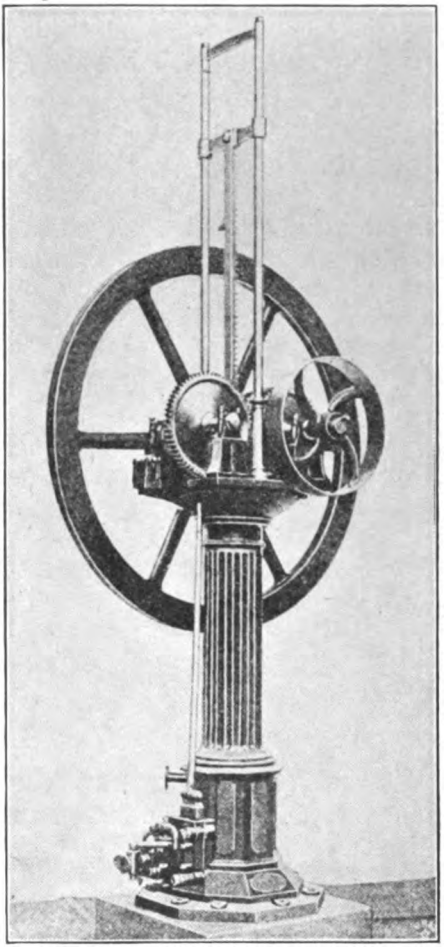
Otto and Langen.

Among the most zealous of those who tried to improve the gas engine, was a young merchant, N. A. Otto, of Köln. His aim was to use the entire stroke for the explosion and expansion. To obtain this, he built an experimental machine in which the engine turned forward for the intake; then the valves were closed and the fly-wheels turned backward to compress the mixture, which was then ignited by hand. The effect was surprising. The ignited mixture, on account of the compression, exploded with such violence that the wheels rotated for some time at a high speed. This was more surprising, since, when the machine was operated without compression, it ran at a low speed. So by these experiments (1861-1862), Otto without foreseeing the results arrived at the compression of the mixture before explosion, ignition at the dead-center, and the accomplishment of the charging, compression, combustion and discharging events in one cylinder—in short, he came on the cycle which is the foundation of the internal combustion engine development throughout the world. Great practical difficulties and insuffi-

Digitized by Google

cient technical experience, however, prevented Otto from appreciating the great advantages of his cycle, and he abandoned it temporarily not realizing how near he was to accomplishing his aim.

The great practical difficulty was that the violent explosions, which even caused trouble in the Lenoir engine, were absolutely intolerable when compression was used. Otto tried to prevent these shocks by substituting in his



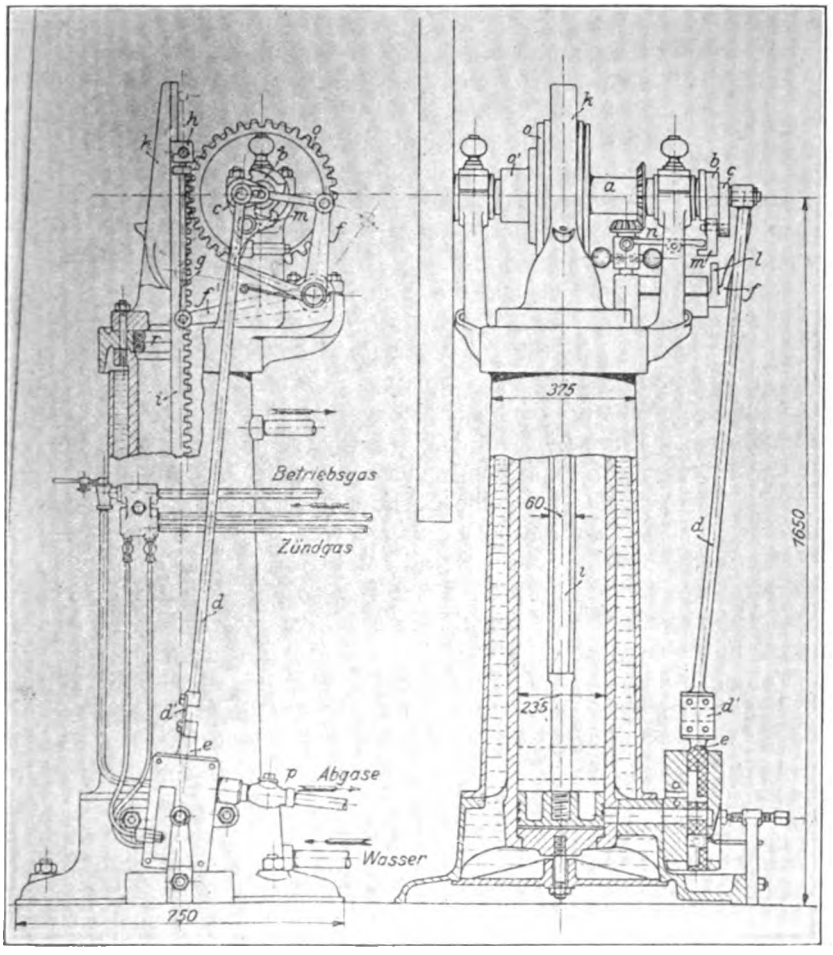
First Otto & Langen Engine.

second experimental engine an elastic member, in place of the usual rigid connection between piston and crank. This was to absorb the shock and transmit the force to the crank gradually. But this experiment was not as successful as he expected, which discouraged Otto to such an extent that he abandoned work on this direct working engine.

A year later we find him experimenting with an atmospheric engine as suggested by the engines of Brown, and Barsanti and Matteucci. He had

Digitized by Google

learned from his second engine that cooling the gases of combustion caused a great decrease in volume. This caused a partial vacuum and Otto endeavored to use this for the generation of power. Fig. 9 shows his original atmospheric engine, which bears a striking resemblance to his second engine, especially in the arrangement of the double free piston. The flat piston (a)



OTTO & LANGEN FREE PISTON ENGINE.

was to be driven upward by the explosion of the gases. A vacuum due to over-expansion and cooling is created in the cylinder. In its upstroke piston (a) displaces the air above it through the non-return clack valve (c) in the main piston. After this both pistons are driven downward by the pressure above.

The hollow piston rod (d) together with the rod from piston (a) forms a dash-pot. Otto procured a patent on this, and by this means was able to

Digitized by Google

form a partnership with the Engineer Eugen Langen, to whom we owe the systematic development of the atmospheric engine.

After many experiments, they perfected their engine in 1867, in time for the Paris Exposition It stood in competition with fourteen direct working engines of French construction, most of which were of the Lenoir or Hugon type. It was very strongly criticised. Laymen were even afraid of the instantaneous ascent of the rack piston rod, and experts were as much annoyed by the clicking noise of the pawls. Opinions, however, were suddenly changed. On account of the strongly urged proposal of the German Prof. Reuleaux, one of the judges, a comparative test was run on all the engines. This test showed the fuel consumption of the three types Lenoir, Hugon, and Otto and Langen to be in the ratio 10:6:4.

On account of its great efficiency, the awkwardness and noise of the Otto and Langen engine were overlooked, and the judges awarded them the first prize. The photograph, Fig. 10, represents the engine exhibited. Every detail was well thought out, and the design showed great originality. The exterior is pleasing and almost beautiful, for the frame and cylinder were made in the form of a Greek column. The later and larger types did not use this ornamentation, as can be seen from Fig. 11.

An interesting feature of this engine was the manner in which the valves were controlled. (Fig. 11.) The valve (e) by one in- and out-stroke causes the exhaust, intake and explosion in the order named. It is moved by rod (d) connected to crank (c). The elastic connection (d′) is unique and is worth notice. Explosion did not occur at every revolution of the fly-wheel and under light load the wheel would rotate for several minutes between explosions. It is clear then that the crank (c) could not rotate continuously with the main shaft. To obtain this intermittent rotation a very ingenious trip mechanism was used. The bell crank (f) is connected to the crank (c) by a link. (b) is a continuously rotating ratchet wheel. (m) is a pawl which can be engaged for rotation with (b). (Shown engaged.) It is, however, kept out of engagement by the arm (1) of the bell crank (f) when desired. The arm (f′) moves with (f) and has connected to it the vertical link (g).

The operation is as follows: When the piston is coming down the arm (1) is in contact with the pawl (m). So (m) is disconnected from (b), and the crank (c) and its connections are stationary. Towards the end of the power stroke the stop (h) on the piston rod descends on the link (g). This moves (f′), (f) and the arm (1) through a small angle. (1) releases (m) which engages (b), and the crank (c) rotates. After one revolution (1) is back in position to disengage the pawl (m) and the rotation of the crank (e) stops. Part of the turn of (c) allows the exhaust of the burnt gases and opens the intake valve. Now (f′) through link (g) and stop (h) lifts the piston several inches to draw in the charge. Then the intake valve closes, the explosion occurs and the valve is stationary until the next exhaust.

The pawl (m) is also controlled by the governor through the arm (n). If the piston at the end of its power stroke causes (1) to release (m) the arm (n) will hold (m) until he speed is below normal, and in this way will retard the next explosion until it is needed.

Digitized by Google

Test of Otto and Langen Free Piston Engine.

The free piston engine of Otto and Langen was given several very accurate tests. Among the most thorough of these, was the test of Prof. Meidinger, of Karlsruhe, in 1868, which covered a period of several weeks.

Bore	5.9 inches
Greatest Stroke	38.6 inches
Suction Stroke	4.1 inches
Weight of piston and piston rod	48.0 pounds
Weight of Flywheel	352.0 pounds
Diameter of Flywheel	49.0 inch

No. of Test	1	2	3	4	5	6	7
R. P. M.	106.	90.	75.	60.	40.	75.	75.
No. of working strokes of piston per minute.	42.	37.	34.	29.	20.	13.	29.
B.H.P. (in metric H.P. which=.85 English (H.P.)	.635	.59	.54	.47	.35	.18	.18
Gas in cu.ft./hr. (including ignition flame)	19.3	18.0	16.0	13.5	10.0	7.5	10.0
Gas per B.H.P. hr. in cu. ft. exclusive of ignition flame	29.5	29.3	28.6	26.8	26.2	35.0	49.0
Proportion of gas in mixture, in percent	12.5	12.5	12.5	12.5	12.5	12.5	8.6
M.E.P. lb/in²	5.8	6.1	6.1	6.25	6.75	5.14	2.35
Economical Effy. in percent $\eta_w =$	13.7	13.8	14.2	15.2	15.4	11.6	8.25

The most economical speed was 75 R. P. M. Tests 6 and 7 run under equal loads. During 6 a "hit and miss" governor was used and in 7 a quality governor was used. The decrease in efficiency in the latter case is very noticeable.

The two ignition flames used 1.5 cubic feet of gas per hour. Since this is independent of the load and of the size of the engine, the ignition gas should be expressed in terms of the H. P. and the following formula gives the proper values:

$$\text{Gas consumption per B.H.P hr.} = \frac{\text{Total consp.} - \text{Ignition Gas}}{\text{B.H.P.}}$$

plus ignition gas. For test (1), for example, consumption per

$$\text{B.H.P. hr.} = \frac{19.3 - 1.5}{.635} + 1.5 = 29.5 \text{ cu. ft.}$$

According to the usual method it would be 19.3/.635 = 30.4 cu. ft. which is 3 per cent greater. At loads greater than one H. P. the effect is the opposite.

For the third test Meidinger computed the heat loss through cooling water and radiation at 2580 B. T. U. per hr. or about 4750 B. T. U. per H. P. hr.

The exhaust had a very bad odor which showed incomplete combustion. The temp. of the exhaust gases was about as follows:

R. P. M.	100	90	60	40
Explos. per min.	45	37	28	20
Temperature	428°F.	396°	358°	284°

Digitized by Google

With very extravagant oiling only .27 lb. of oil was used in a 12 hour run. In test 3 the average velocity of the piston for a complete up and down stroke was 3.9'/sec. The average speed on the up-stroke, however, exceeded 45'/sec.

Reithmann and Aimüller.

At the time when Otto and Langen worked on their atmospheric gas engine, a very interesting double acting free piston engine was originated in Munich. For six years (1867-73) this small engine was running in the shop of its inventor and builder, Christian Reithmann. In 1873 he successfully remodeled this engine into a four cycle machine.

The first engine had two pistons working in one cylinder. His engine, however, required a very complicated pawl arrangement, which often caused trouble and was one of the chief reasons why it was remodeled. No tests were available.

b. Gas Engine With Compression.

The compression of the charge was the most important step in the development of the internal combustion engine, and perhaps never again will a single improvement cause such an increase in efficiency as was the case with the utilization of compression. Compression was casually mentioned even in the old patent specifications of Lebon, Wright, Barnett and others, however, definite knowledge of its effect on the efficiency was lacking and practical suggestions as to its use were not made until he Lenoir engine had appeared.

Gustave Schmidt, a German engineer and man of science, was the first one publicly to suggest the use of compression. In a lecture in the Wien Polytechnic Institute in 1861 he stated: "Results would be much more satisfactory if compressors would be provided to compress the cold charge to about 3 atmospheres before admission, by which a better expansion and higher efficiency would be obtained."

Only one machine was built according to this idea, but his suggestion of lengthening the cylinder to provide clearance was a good one and being followed later has since been constantly used. It was at about this time that Otto was experimenting with his first compression engine as described earlier

Early in 1862 Beau de Rochas, a French civil railway engineer, published a paper which, was really a treatise on steam engines, contained some good suggestions for the improvement of the gas engine. Beau de Rochas even recommends that the compression be carried on trial till ignition occurs. He estimates the pressure required for ignition at 6 atmos., and the resulting explosion pressure at 30 atmos. The contents of this paper, however, did not become generally known until it was brought up during the Otto patent suits 20 years later. Other good suggestions concerning the use of compression were made by the well-known German engineer, Wm. Siemens. His aim was to utilize the heat of the exhaust gases in regenerators. His English patents, taken out 1860 to 1864, concern a special kind of engine in which the charge was led through the regenerators and so preheated before

Digitized by Google

ignition. Combustion was to take place at constant pressure. This cycle was used later in the so-called "constant pressure engines." Siemens never made practical application of his ideas.

(1) Constant Pressure Engines.

Brayton.

Curiously, the first constant pressure compression engine was built in America. This engine was introduced by Brayton at Philadelphia in 1873. As in the Otto types, the charge was compressed, but otherwise this engine differed from all earlier types, and illustrated the principle of combustion at constant pressure instead of at constant volume. It was a single acting, two cycle motor with an impulse at every revolution. After compression by a separate pump, the gas and air were delivered into the motor cylinder, but they were not admitted cold and then ignited and exploded, according to the usual cycle of operations. A small flame in direct communication with the cylinder was kept constantly alight, and kindled the gases as they passed it. Thus they were gradually ignited, and entering as flame, drove the piston forward, not by the pressure of explosion but of combustion. The heat was imparted to the gas at constant pressure—that is, the piston moved as soon as the flames began to enter the cylinder, but there was no sudden explosion. A wire gauze was fixed behind the light, to prevent the flame from striking back into the compression chamber. This method of ignition worked well as long as the wire gauze remained intact, but holes were liable to burn into it, and when this occurred the flames struck back into the compressed gases and a serious explosion followed. If this did not entirely wreck the engine, it at least extinguished the ignition flame and stopped the engine. On this account Brayton abandoned the use of gas in his engine and substituted petroleum vapor.

Test of Brayton Engine.

But very few tests of this short-lived engine were made and these are incomplete. The test made by Prof. Thurston will be given here:—

Nominal Rating 5 H.P. B.H.P., 398; I.H.P., 8.62.
Gas consumption per I.H.P. hr., 32 cu. ft.; Mech. Effy, 46 per cent.

These results are incorrect, since the work in the pump is included in the I. H. P. The true I. H. P. is the difference between that indicated and the work of the pump.

$$\text{True I.H.P.} = 8.62 - 3.5 = 5.12 \text{ I.H.P.}$$

$$\text{Mech. Effy. } n_m = \frac{3.98}{5.12} = 78 \text{ per cent.}$$

$$\text{Gas Consumption per I.H.P. hr.} = \frac{8.62 \times 32}{8.62 - 3.5} = 54.4 \text{ cu. ft.}$$

$n_i = 8.2$ per cent.

$$\text{Gas Consumption per B.H.P. hr.} = \frac{54.4}{.78} = 69.7 \text{ cu. ft.}$$

$n_w = 6.4$ per cent.

In spite of the compression, the efficiency of this engine was lower than that of the Otto and Langen engine, but it was, (1/3) one-third higher than that of the Lenoir engine.

Digitized by Google

Simon Engine.

Simon and Beechy of Nottingham, the English licensees of Brayton's patents, attempted to improve the Brayton engine by adding a boiler to the already complicated machine. The boiler was placed above the cylinder, and the exhaust gases furnished the heat for the evaporation of the water. The steam produced and injected into the motor cylinder increased the expansive action of the gases and helped to lubricate the piston. This idea was not a novelty. It had been tried by Hugon, but neither his engine nor the Simon was practically improved by it. On this point Professor Schöttler pertinently asks—"Whether it can be considered an advantage, since the gas engine is expressly designed to avoid the defects and dangers of the steam boiler, to add the latter to it."

Diesel Gas Engine.

In the same class with he Brayton and Simon constant pressure gas engines, is the attempt of Diesel, twenty years later, to build a constant pressure gas engine, after he had successfully built his exceedingly efficient oil engine. The highly compressed fuel was injected through a needle valve into the cylinder, which contained air under high pressure. As in the Brayton and Simon engines, combustion was to occur at constant pressure. Various factors caused the engine to be unsatisfactory. A heat efficiency of 27 per cent was obtained, but before that time an efficiency of 36 per cent had been obtained by Diesel's oil engine. Combustion was incomplete on account of improper mixing of the gas and air. This was the case even when the gases used were rich and was much more noticeable when they were poor.

From the three examples, Brayton, Simon and this attempt of Diesel, it is apparent that a practical and economical *constant* pressure *gas* engine has been found almost an impossibility.

b_1. Explosion Engines.

If intake and compression of the change occur in the working cylinder itself, instead of in a special charging pump, we have what is practically the "four-cycle" principle. By this combination of working cylinder and charging pump into one cylinder, four strokes of the piston are necessary for every power impulse. Three of these strokes are only a preparation of the charge, and one is the working stroke.

First Revolution. (Machine acting as charging pump.)	(First outstroke) Intake.
	(First instroke) Compression.
Second Revolution. (Machine acting as engine.)	(Second outstroke) Working.
	(Second instroke) Exhaust.

To the Gas-Moteren Fabrik Deutz was given the German government patent No. 532, protecting the four-cycle principle. This patent, dated Aug. 4, 1874, gave Dr. Otto's company a monopoly on four-cycle construction. Suit to set this patent aside was filed by a number of other manufactures and in 1886, after a four years trial, one of the patent clauses was nullified

Digitized by Google

by the courts, and the four-cycle principle became common property. Two-cycle engines, which had become common during the Deutz four-cycle monopoly, disappeared almost entirely.

This patent decision had a wonderful effect on the gas engine industry, as well as on other industries, and was the end of the most important trial of that period, and the beginning of a new epoch of development.

The reasons for the decision were two in number:

First, Beau de Rochas had, as early as 1861, published a pamphlet recommending the four-cycle engine, and had in 1862 procured the French patent on same. Second, in 1873, one year before the date of Otto's patent and four years before the construction of the Otto four-cycle engine, Christian Reithmann, a jeweler of Munich, had a successful four-cycle engine in operation in his shop, which he used for many years for driving his machines.

It cannot be claimed therefore that Otto was the inventor or even the first builder of the engine named after him, although it should be said in justice to him that his work seems to have been done without knowledge of the work of Beau de Rochas or of Reithmann, and that he accomplished the most successful pioneer work in gas engine construction.

Beau de Rochas.

The idea of the four-cycle engine was, without doubt, first originated in the mind of Alphonse Beau de Rochas, a French railway engineer. It was published in a pamphlet in 1861, and a part of his suggestion is given herewith, "the following operations must then take place on one side of the cylinder, during one period of four consecutive strokes:

I. Drawing in the charge during one whole piston stroke.

II. Compression during the following stroke.

III. Inflamation at the dead point, and expansion during the third stroke.

IV. Discharge of the burnt gases from the cylinder during the fourth and last stroke."

Beau de Rochas never constructed an engine according to his suggestions. It is apparent that he did not see or at least did not explain how to practically apply his ideas. He evidently understood that a clearance space would be necessary in an engine of his description and that part of the burnt gases would remain in the cylinder. But he did not give any suggestion as to the effect of these gases on the combustion of the next charge.

Reithmann.

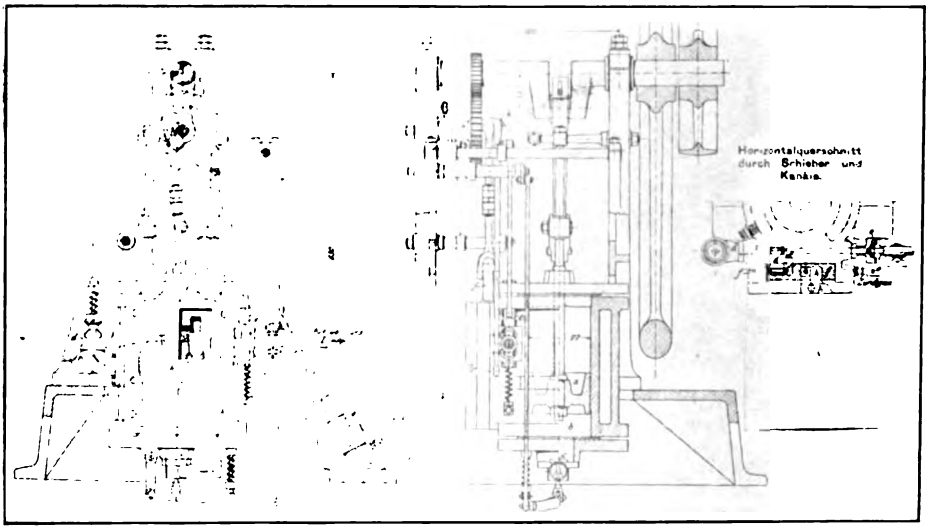
As above stated Reithmann built the first four-cycle gas engine in 1872-73. Fig. 12 is a cross-sectional view of this engine.

On page 16 we gave a short description of Reithmann's and Aimüller's double acting atmospheric free piston engine. In spite of Reithmann's wonderful work very little credit or recognition has been given him until recently. Not a word concerning this engine can be found in English text-

Digitized by Google

books, and the first recognition given him in German scientific circles was in 1902 when Güldner published his well-known book, "Entwerfen, und Berechnen der Verbrennungs Motoren."

Below the piston (a) is the clearance space (b) at the bottom of which is placed the exhaust valve (c). From the air valve (d) and the small gas valve (e) a channel leads to the cylinder through the large slide valve (f). Ignition occurs by means of a flame and flame-valve. The air and gas inlet valves, the exhaust valve and the ignition apparatus are controlled by the half speed shaft (i).



REITHMANN 4-CYCLE ENGINE.

During the first one-third of the first outstroke the piston draws in air only through the valve (d), then the valve (e) opens and gas and air are drawn in together until the stroke is completed. At the upper dead point the values (d) and (e) are closed and the downstroke compresses the charge. Ignition occurs at the lower dead point and the gases expand during a complete stroke. The exhaust valve opens at the upper dead point.

The engine ran at about 200 R. P. M. and at this speed developed ¾ H. P.

Otto.

(1861). The second attempt of Otto to build a gas engine was in 1861-62 when he built the machine sketched in Fig. 13. The four cylinders each contained two pistons; the pistons (a) were secured to the piston rods (c), while the pistons (b) were loose in their cylinders. (See page 13). The object of this construction was to have the shock of the explosion in the combustion cylinder taken up by the piston (b) and gradually transmitted to the piston (a) by means of the air cushion between the two. During the exhaust stroke the air between the pistons was to expand and drive the loose

Digitized by Google

piston to the extreme end of the cylinder. This was a very ingenious way of obtaining perfect scavenging in an engine using compression.

Otto never got this engine started. There were several reasons why it was impractical. First, the excessive noise and wear due to the loose auxiliary pistons. Second, the variable point of ignition. Third, the perfect scavenging of the cylinders caused very sudden explosions which produced intense shocks on the engine parts.

After Otto had worked for one year in a vain attempt to overcome

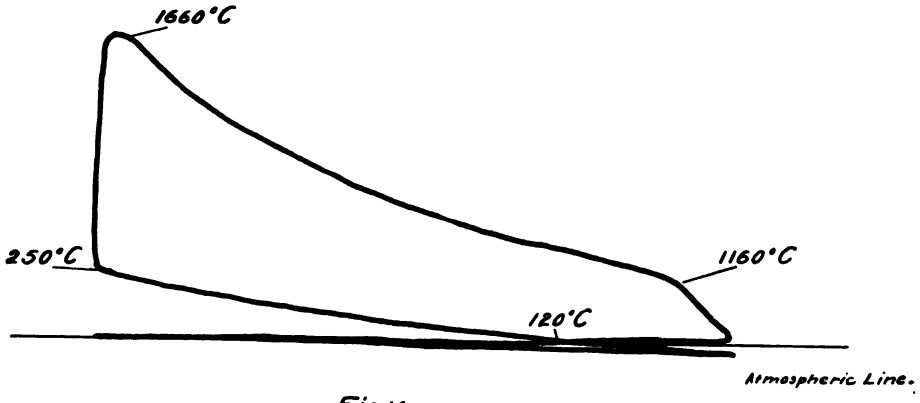


Fig. 14
Normal Indicator Diagram from 6 H.P. New Otto Engine
8" Cylinder diam., 14" Stroke, 160 R.P.M.

these difficulties he abandoned this type of engine and applied himself for 15 years to the development of the Otto and Langen free piston engine (as described earlier).

Otto.

(1877). Otto's third engine was introduced to the public at the Paris Exposition of 1878, similar to the introduction of the Otto and Langen engine a decade earlier. Seventy-five engines were exhibited at the exposition. Among these were several engines of "the new Otto four-cycle type." The gas consumption of these Otto engines was approximately equal to that of the Otto and Langen atmospheric engine (economical efficiency 15%), but the engines distinguished themselves from those of other firms by their quiet, steady motion, small floor space, much greater specific capacity, and above all, the combination of charging pump and gas engine in one cylinder, advantages which soon made this engine favorably known throughout the world.

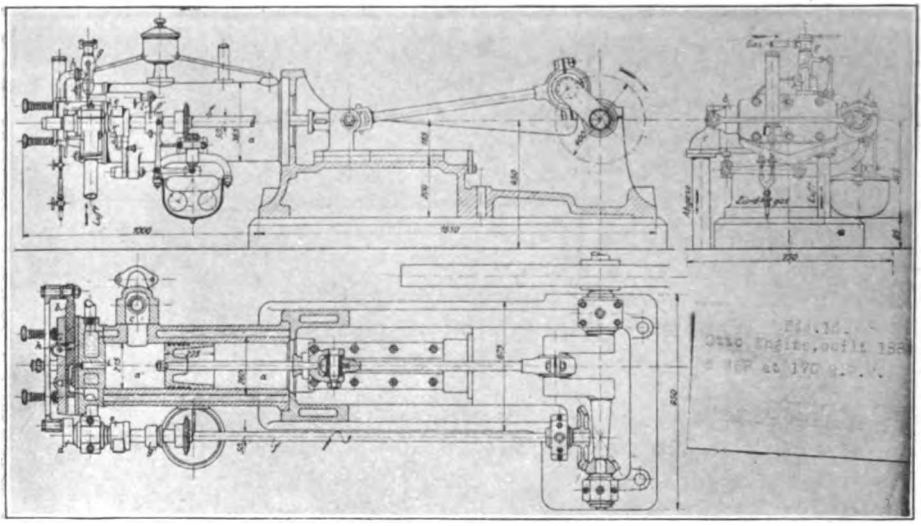
The great simplicity obtained by the alternate use of the cylinder as pump and motor, diminishes the number of valves necessary and reduces the resistance to the incoming gases, while entirely preventing any loss due to ports, in transferring the gases from one cylinder to another. The carrying out of the cycle is mechanically almost perfect, little work being spent

Digitized by Google

which is not included in the theory. Furthermore, the piston is fully in at the moment of ignition, and is practically at rest. The heat, producing maximum temperature, is therefore added at nearly constant volume. The highest pressure which the gas present is capable of producing is, therefore, attained at the beginning of the stroke simultaneously with the highest temperature. The expansion is very rapid, and so no unnecessary waste of heat occurs, since the temperature is rapidly depressed by the work being done. The united effect of all these factors can be seen in the perfect diagram in Fig. 14.

The losses incurred in the operation of the cycle will be fully discussed later in lectures on the thermodynamics of the internal combustion engine.

One of the first "new Otto" engines is shown in Fig. 15. The cylinder (a) has a clearance space (a') about 2/3 of the piston displacement. The



OTTO ENGINE, 1884.

entrance of the gas and air, as well as the ignition, is controlled by the slide valve (b). Exhaust occurs through the valve (c). (b) is operated by the small crank (d) while (c) is controlled by the cam (e), both being connected to the half-speed shaft (f). The gas valve (g) is operated by the cam (g').

At the beginning of the intake stroke the exhaust valve (c) is closed, while the slide valve (b) has moved its air channel to communicate with the channel (i) of the cylinder head. Air alone is drawn in for the first part of the stroke, which is supposed to force the burnt gases of the clearance space against the receding piston. In the meantime the valve (b) has moved far enough to open the gas inlet, while the cam (g') has opened the gas valve (g), so that gas and air enter the cylinder simultaneously to the end of the stroke. Now the slide (b) closes the port (i) and the charge is compressed into the clearance space by the returning piston. During this

Digitized by Google

time the slide (b) has moved to the right, and the ignition port (k) is opposite the part (i) so that flame is carried through (i) into the clearance space (a'). Ignition occurs on dead center and the charge explodes to about 10 at. pressure. At the end of the expansion stroke the valve (c) is opened and exhaust occurs during the next stroke. The burnt gases in the compression space cannot be expelled, but remain and become a part of the next charge.

Governing is by the "hit and miss" principle. When the speed rises above normal, the governor shifts the cam (g') along the shaft (f), until the came no longer strikes the lever (1) of the valve (g). The latter remains closed and the engine misses until the speed drops to normal. During these strokes only air is drawn in and the cylinder is thoroughly scavenged. That this has a good influence can be seen from the diagram of Fig. 16.

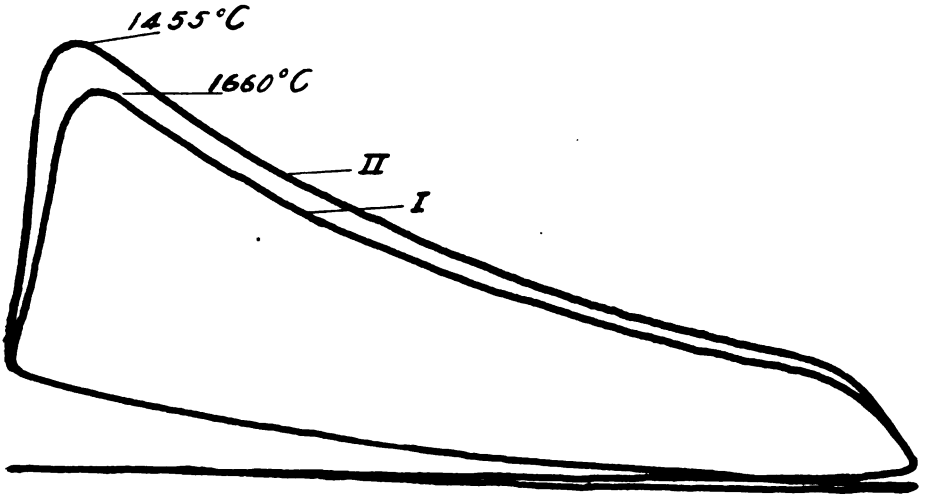


Fig. 16.
I Diagram with Regular Action, II Diagram after a Miss-fire of 6 H.P. New Otto Engine.

Later (for precision regulation) instead of the cylindrical cam (g'), a conical cam was used, which operated so that when above normal speed the gas valve (g) was only partially opened. Less gas entered and the ratio of gas and air was decreased, the quantity of the charge being constant.

The composition and arrangement of the charge in the cylinder of Otto's engine remained an open question for many years, and played an important part in the suits against Patent 532. Otto believed that the economy of his engine was due to a certain stratification of the gases of the charge, which view was defended by Prof. Slaby and other authorities on

Digitized by Google

thermo-dynamics. In his patent claims Otto states, "At the end of the intake stroke, three distinct layers, or strata, of gas are present in the cylinder; next to the piston is a layer of burnt gases remaining from the previous explosion. The second layer is pure air admitted during the first part of the intake stroke, and the third strata, a mixture of gas and air, is located next to the cylinder head. This stratification is probably partly lost during compression, but the order is retained, although the divisions may not be clearly defined. When the charge is ignited at the dead center, the flame does not immediately fill the whole cylinder, but begins with the richest mixture near the cylinder head and is gradually propogated from layer to layer until the whole charge is burnt. The combustion, therefore, is not a sudden one, but purposely retarded to prevent the shock of a sudden explosion." In order to facilitate this formation of strata, Otto originally used a conical clearance space, which he later abandoned in favor of a long inlet channel.

That there really was a gradual combustion of the charge in Otto's first engines, (which was nothing more than a decided "afterburning") is shown by indicator cards of his engine. (See Fig. 17.) For this purpose, however, it is not necessary to have a stratified charge, for every improperly mixed or poorly ignited charge burns slowly, especially when low compression pressure is used, as was the case in the early Otto engines. The phenomenon of slow combustion, which Otto considered as the principal cause of the efficiency and smooth operation of his engine, is today rightly considered an undesirable condition and is prevented when possible. This question has been discussed by many well-known experts on Internal Combustion Engineering and is not completely settled today. A good discussion is given in Clerk Gas Petrol and Oil Engines, pages 37 to 47, and Zeitschrift der Vereines Deutscher Ing. Vol. XXX, page 209.

Otto engines in small sizes, (1-6 to ½ H. P.) were sold in great numbers and supplied a real want in small industries. In these types the valves were simplified, the inlet slide was abolished and one valve controlled the gas and air intake. Later hot tube and electric ignition was used. About this time the crosshead was considered unnecessary and the simple construction common today was adopted.

The capacity also was developed greatly. In 1878 the largest engine sold was 4 H. P.; in 1880, 20 H. P.; 1885, 80 H. P.; 1889, 100 H. P.; in 1893, 200 H. P.; in 1900, 1000 H. P., and in 1910 engines of 4000 H. P. units were delivered.

The gradual increase in capacity and efficiency was properly accompanied by many experiments along new lines. The most important of these was a three cylinder "compound" engine built in 1879 for the purpose of increasing the efficiency by increased expansion. The two outside cylinders operated alternately in the usual 4-cycle way, but exhausted their gases after partial expansion into the center cylinder where they were completely expanded. This (center) cylinder, therefore gave an impulse every revolution. The engine gave satisfactory results and was commercially operated for many years, but today is no longer built.

Digitized by Google

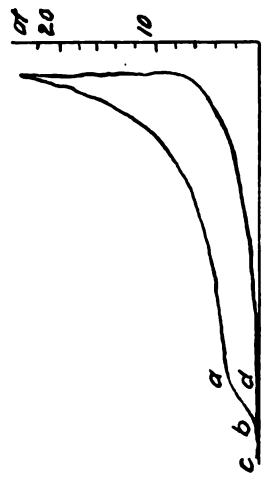


Fig. 23

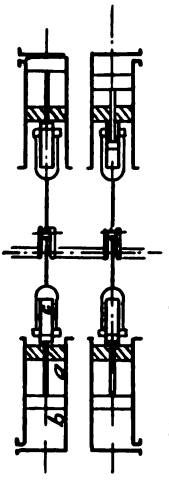


Fig 13 Otros four-cycle engine with four cylinders

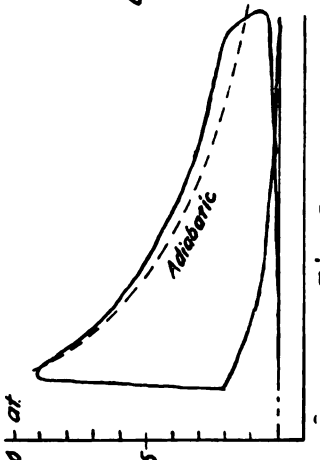


Fig 17

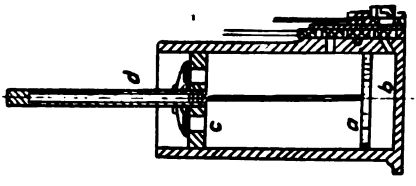


Fig 9 Otros free piston engine

Digitized by Google

Test of Otto Engines.

Tests of Slaby and Brauer, of Original Otto engines of the horizontal crosshead type. Test 1 to 3 were carried out in 1878, jointly by Prof. Slaby and Brauer. Test 4 was run in 1881 by Slaby alone.

No. of Test	1	2	3	4
Bore	5.5"		6.7"	6.75"
Stroke	7.08"		13.6"	13.4"
R. P. M.	184.	180.	159.4	156.7
Explosion P. M.	44.	77.	79.	78.35
B. H. P.	1.08	2.20	3.98	4.46
Mean Indicated Press.	69.5 lb/in²	61.2	63.8	53.
I. H. P.	2.06	3.20	5.73	5.11
Mech. Effy.	25%	65%	69.5%	67%
Gas per B. H. P. (cu.ft. hour	49.	40.	37.8	38.2
Explosion Press. in lb/in² P_e		34.5	41.	46.
Economical Effy. η_w	9.1	11.2	11.2	12.

For the engine of Test 4 the following determinations were made:

Proportion of gas in charge	12.2%	
Compression press	2.43	atmosphere
Explosion	9.6	atmosphere
Cooling water for B. H. P. hr.	12.7	gallons
Heat loss through cooling water per B. H. P. hr.	8950.	B. T. U.
Explosion temp.	1125°C	Abs.
Exhaust temp.	802°C	Abs.

Heat Balance 16.5 B. T. U. transformed into water.
Heat Balance 32.3 B. T. U. loss in exhaust.
Heat Balance 31.2 B. T. U. loss cooling water.

After Otto.

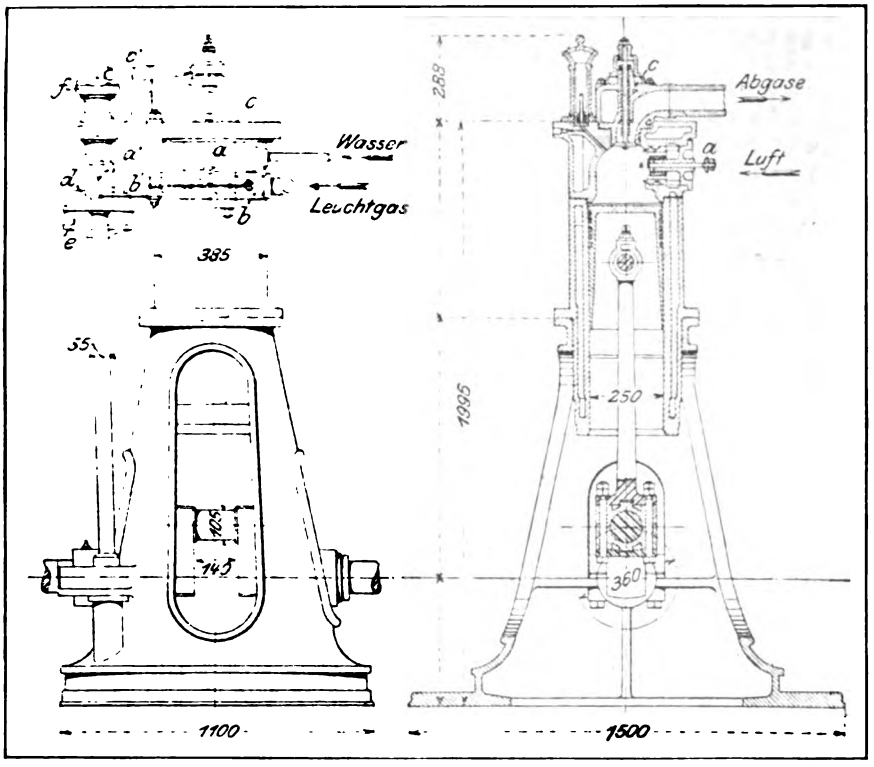
Immediately after the nullification of Clause 4 of the Deutz Co., Patent No. 532 (Jan. 1886), many new types of four-cycle engines appeared on the market. Most of them, however, were soon abandoned. In the next few pages only those engines of this period will be mentioned that have some special feature or an unusual efficiency to recommend them to our attention.

During the first few years Otto developed only the horizontal slide valve engine, but most of his competitors adopted the vertical type poppet valve engine with crank shaft above the cylinder.

Loutzky.

The first constructor to get away from this general type was the German engineer, Loutzky, who built an engine with cylinder above. In 1888 he exhibited an engine of this type provided with hot tube ignition. By a unique arrangement of the valves in the cylinder head he obtained an approximately hemispherical compression space, entirely free from channels or pockets. (See Fig. 18.) He obtained an efficiency that is seldom excelled even now, although he used a compression of only 4 at. The efficiency must, therefore, be attributed to the shape of the compression space.

Digitized by Google



LOUTZKY ENGINE, 1895.

Delamare-Debouttcville and Malandin.

The French Engineers Delamare, Debouttcville and Malandin introduced a small four-cycle engine, their "Moteur Simplex," in 1884. These daring French engineers showed great initiative in the design of large engines. In 1889 they exhibited a 100 H. P. one cylinder, single acting engine, using a 6 to 8 at. compression pressure and 20-22 at. explosion pressure, a construction that was certainly remarkable in view of the inferior materials of construction and the limited knowledge of design at that period. Within five years, however, they followed with engines of 300, 700 and then 1000 H. P. in one cylinder. The dimensions of the latter engine were 51" bore, 56" stroke and a speed of 80 R. P. M. Later (1901) the well-known machine company, Cockerill, of Seraing, built these engines in the double-acting type.

Charon.

Charon was one of the first to attempt "increased expansion" as a means of increasing the efficiency. He obtains this by the simple means of allowing part of he charge taken in to be expelled back into a specially provided chamber. Compression does not begin until near the middle of the com-

Digitized by Google

pression stroke. In this way he obtains a low volumetrc efficiency but a high expansion. The governor controlled the amount of the charge expelled before compression and in this way regulated the speed. The efficiency, though fairly good, was not as high as might have been expected from the great expansion obtained. This was attributed to the fact, that since the clearance volume remained constant and the volume of the charge varied, the compression pressure also varied. (The most efficient comp. press. was obtained with a full charge). The efficiency, therefore, increased rapidly with the load from 11% at 1-3 load to 26.4% at full load.

Crossley Brothers (Manchester, England).

This firm, though formerly the English licensees of Otto's patents, soon became independent. They developed several lines of engines of very unlike construction. One of these was the "Scavenging Engine" designed by Atkinson in 1892, in which he made use of the momentum of the exhaust gases for drawing a charge of air through the clearance space at the end of the exhaust stroke. To increase the momentum, he used a long (Clerk gives 65 feet) straight, and uniform exhaust pipe. Toward the end of the exhaust stroke, when the velocity of the piston decreases, the momentum of the gas column in the exhaust pipe causes a partial vacuum in the clearance space. By opening the air valve at this time, a charge of air was drawn through the clearance space and out of the exhaust ports. This is completed when the piston was moved out one-tenth of its stroke. Then the exhaust closes and the intake begins.

This engine had several disadvantages which quite overbalanced the perfect scavenging obtained.

Westinghouse.

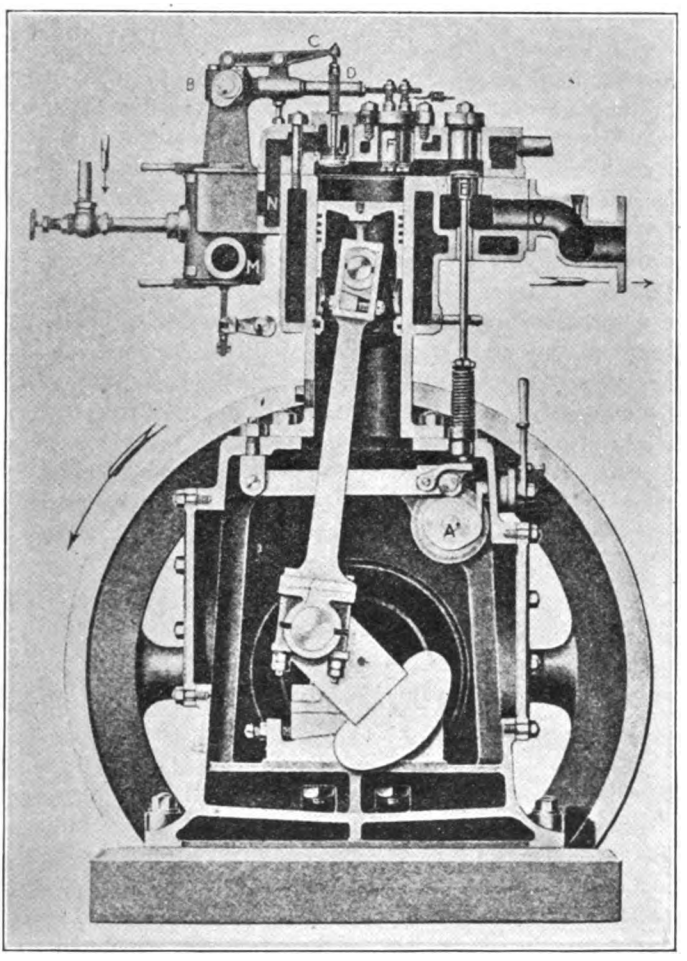
After many experiments, the Westinghouse Machine Co., of Pittsburg, produced a vertical (4-cycle) gas engine in 1896, which has many interesting features. This engine resembled their vertical steam engine. (See same in Lab.) It was the first practical 4-cycle American made engine put on the market. In 10 to 85 H. P. sizes, two cylinders were used, with cranks arranged on same side of shaft. Large models up to 600 H. P. had 3 cylinders with cranks at an angle of 120°. The design of all these engines provided for good balancing of the parts.

(Fig. 19.) The half-speed cam shaft (A) operates only the exhaust valve (E). Two shafts, not shown in Fig. 19, connect shaft (A) with the half-speed shaft (B), which operates the inlet valve (j) by means of the lever (C) and igniter (F) through the rod (D). The mixing valve (M) supplies all the cylinders and is connected with the various inlet parts by means of the manifolds (M). (M) contains a balanced valve by means of which the governor throttles the gas and air supply. This is the first example of a quantity governor we have met. The water-jacket is extended along the cylinder only as far as the top of the piston when it is in its lowest position. The cooling water outlet is usually connected to the exhaust pipe (o), to avoid the use of a special water pipe and also to assist in cooling

Digitized by Google

the exhaust valve (E). The water is expelled with the exhaust. The crank case is partly filled with oil, and the lubrication of crank shaft, connecting rod and piston is by the "splash system."

In order to start the larger engines one of the cylinders is operated by compressed air until the other two have begun exploding. For starting, a



WESTINGHOUSE ENGINE.

special set of cams to operate one of the cylinders in two-cycle, is provided. These can be controlled by the lever shown to the right of shaft A in Fig. 19.

Many tests of Westinghouse engines of this type have been made and various results obtained. The mechanical efficiency runs as high as 90%, the thermal efficiency as high as 25½% and the M. E. P. over 6 1-3 atmospheres. The effect of the short water-jacket was two-fold. A favorable effect was the decrease in amount of cooling water; an unfavorable effect was the

Digitized by Google

increased temperature of the exhaust gases. For this reason we have an unusual heat balance:

Heat transformed into work 28.5%
Heat lost in exhaust and radiation 40.8%
Heat lost to cooling water 38.7%
"Compare with heat balance of Otto engine, page 24."

Rollason-Beck.

This English engine uses the six-stroke cycle, in which the 5th stroke draws in air through the inlet valve and the sixth-stroke expels it through the exhaust. The purpose of this extra revolution is to get better scavenging than is possible with the 4-stroke cycle. Schöttler suggests that the six-cycle was used only to avoid infringing Otto's patents. Whatever the original motive may have been it is a fact that these engines were made long after Otto's monopoly had been removed in 1886.

An interesting feature of this engine was the use of an air jacket between water jacket and cylinder walls to prevent undue heat losses to the cooling water.

The six-cycle does not require any unusual constructive features, except that the cam shaft has 1-3 the speed of the crank shaft and that two extra cams are provided to open the inlet and exhaust valves during the 5th and 6th stroke respectively. The expansion obtained in this engine was almost a perfect adiabatic, which shows that the extra attention given to scavenging was not wihout good results.

Griffin.

This English engine was also of the six-cycle type, but was double acting. We see that where steadiness of operation, or high power was required, designs returned to the double acting engine.

General.

The development of the four-cycle engine has been very rapid in the last 15 years, but the study of these modern engines, enumerated on page 5, A, b, b′, a″, 11-19, especially of their mechanical details, can better be done by inspection of the engines themselves, and by the study of the catalogs and trade bulletins of manufacturers.

(b_2). The Two-Stroke Cycle.

The denomination of internal combustion engines according to their cycle was not followed until after the introduction of the "new Otto," the operation of which could best be named by the number of strokes required for a full working cycle. Formerly they distinguished only between the "single acting" and the "double acting" types, which distinction is used today only in connection with the name of the cycle.

After Otto had shown that even a compressed mixture could be exploded in an engine cylinder without harmful shocks, many attempts were

Digitized by Google

made to apply compression to two-cycle engines. Very few foresaw the real value of the four-cycle. In comparison with the steam or the Lenoir engine there was a tendency to consider Otto's "half acting cycle" as a retrogression. And the construction of the two-cycle engine seemed so simple! But later, when it was shown that on account of practical difficulties, the two-cycle could not be built to run as efficiently as the four-cycle, the opinion was suddenly reversed. The Deutz four-cycle monopoly, which had hardly been noticed before this, handicapped the whole industry, and other German manufactures carried on the fight against Patent 532, until the four-cycle was given free to the world. And this meant the undeserved downfall of the two-cycle engine, at a time when it was only partially developed.

Purely from a technical point of view, the nullification of the four-cycle patents was a great disadvantage to the whole gas engine industry. The monopoly of four-cycle construction had forced the study and development of the two-cycle.

For more than ten years, work on two-cycle engines was abandoned, but was resumed in the nineties, and two-cycle engines, even in very large sizes, are commercially built today. Competition between the two-cycle and four-cycle types is strong even now, although the four-cycle is still leading. It is an open question among experts as to which engine will have the supremacy in the future.

Two-cycle engines can be classified according to their manner of removing the exhaust gases:

1. Expelling Engine.
2. Scavenging Engine.
3. Suction or Exhauster Engine.

1. In this engine the exhaust gases are forced out by the instroke of the piston. In the Lenoir and other early engines this method was used.

2. In this type, air under about 4 or 5 pounds gage pressure is used to flush out the clearance space.

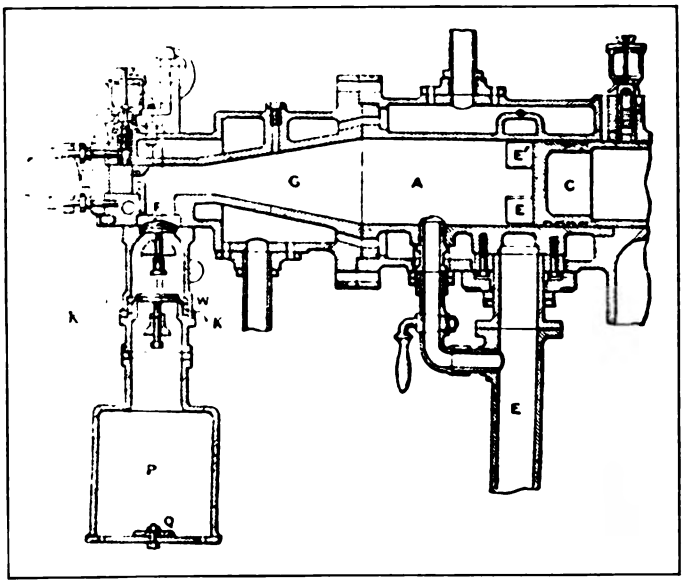
Examples: Clerk, Oechelhauser and Junkers, Benz, Mietz, and Weiss and others.

3. In this type, a special pump was provided to draw the exhaust gases out of he clearance space. Examples: Dr. Lange, Radovanovic.

Clerk.

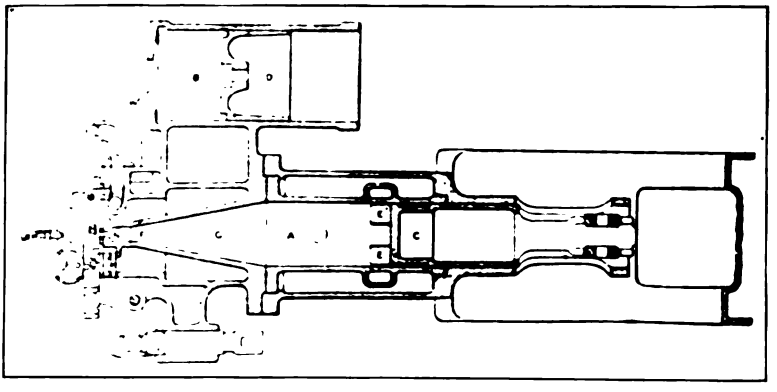
Perhaps the earliest fairly successful worker was Clerk, who commenced to experiment upon two-cycle engines soon after Otto perfected his four-cycle machine. It was, however, not until 1880 that he succeeded in producing a serviceable machine. Fig. 20 and 21, both from Clerk, "The Gas and Oil Engine," show a vertical and horizontal cross-section respectively. The operation of the engine is as follows: In Fig. 21 the power piston, C, has just reached the outer dead center and the main bulk of the exhaust gases have escaped through the ports E E′. In the meantime the displacer piston, D, which on its previous suction stroke has drawn a mixture

Digitized by Google



CLERK ENGINE, VERTICAL SECTION.

of air and gas into B, has completed about half of its in stroke and displaced the mixture into G and A through the connecting pipe, E. About the time D has completed its in stroke, the piston C, has covered the exhaust ports on its return stroke, and compression ensues inthe main cylinder. The cylinder volumes are so proportioned that in theory no mixture can be lost through the exhaust ports. At the inner dead center of the power piston, C, or just before, the igniting cavity, O, Fig. 21, comes opposite the port, N, and the charge is fired. The piston is impelled forward and the next charge, drawn into B in the meantime, commences to enter the space G as soon as the pressure in A has fallen enough, after the beginning of exhaust, to cause the valve in the pipe between B and O to lift. The intermediate valve arrangement is shown in Fig. 20. P is an air chamber. The air drawn in by



CLERK ENGINE, HORIZONTAL SECTION.

Digitized by Google

the suction of the displacer piston, D, passes through the valve, H, and in so doing is mixed with gas which enters through a number of fine holes in the seat of the valve from the annular space, K. On the in stroke of the displacer piston the mixture under some pressure comes in under the valve, F, which it lifts as soon as the pressure of the exhaust gases above it has fallen low enough.

The difficulty under which the engine labored was loss of mixture through the exhaust ports and consequent low economy. Although the respective volumes of the two cylinders may be in the proper ratio, the charge expands by heat on the transfer, and mechanical agitation favors the loss. In spite of this defect shopt tests on 2, 4, 6, 8, and 12 horse-power engines in 1885 gave results fully equal to those obtained on the four-cycle machine of that day. The following table shows the results of some of these tests.

Horse-power.	2	4	6	8	12
Dia. Motor Cyl., inches	.5	.6	.7	.8	.9
Stroke Motor Cyl., inches	.8	.10	.12	.16	.20
Dia., Displacer, inches	.6	.7	.7½	.10	.10
Stroke Displacer, inches	.9	.11	.12	.10	.20
R. P. M.	.212	.100	.146	.142	.132
I. H. P.	3.62	8.68	9.05	17.38	27.46
D. H. P.	2.70	5.63	7.23	13.69	23.21
Mech. Eff., %	74.7	65.0	80.0	78.8	84.5
Gas per B. H. P.—hr., cu. ft.	40.0	37.3	30.42	26.58	24.12

Wittig and Hees.

This engine, built in Linden in 1880, had two cylinders with coincident cranks. One of these was the working cylinder and the other was a pump to compress the charge. While the motor cylinder was making its out-stroke, the pump drew in a charge. The exhaust valve opened on the outer dead point and remained so for .6 to .7 of the return stroke. At this point it was closed, the intake valve opened, and the charge, which had been compressed in the pump in the meantime, was transferred to the motor cylinder and further compressed during the remainder of the stroke. Ignition occurred at the inner dead point.

The efficiency of this engine was very much lower than Otto's engines of that period. Also, the operation was not dependable, and dangerous explosions in the charging pump were of frequent occurrence.

Benz.

The firm Benz and Co., of Mannheim, built their first two-cycle engine in 1884. This engine was of the horizontal cross-head type. It was, however, single-acting, since the crank end of the cylinder was used as a compression pump. On the instroke the pump drew in air and discharged, during the outstroke, into a receiver in the base of the engine, where a pressure of 3 to 6 lbs. per square inch was maintained. The cylinder exhaust opened at the end of the expansion stroke and the pressure rapidly dropped to atmospheric. When the cylinder pressure equaled the receiver pressure,

Digitized by Google

the air valve opened and a quantity of air swept through the cylinder and out of the exhaust pipe to scavenge the clearance space. At the middle of the instroke the exhaust closed, a moment later the intake valve. Compression occurred during the rest of the stroke. In the meantime, a small gas pump, the piston of which is connected to the crosshead, discharged a quantity of gas into the cylinder. Ignition by means of an electric spark occurred at the inner dead point.

The efficiency of this engine was satisfactory at normal load, unsatisfactory, however, at low loads. The manufacture was given, up by the Benz Co., in 1894, although engines of this type were built by other firms for a number of years.

Mietz and Weiss

This engine, made in New York, has enjoyed an extensive sale in this country and Europe. It is a close copy of the German engine of Söhnlein. (See engine in Mechanical Lab.).

Oechelhäuser and Junkers.

This two-cycle engine had three cranks, operating two pistons in one cylinder. The first engine was built in 1893. Construction is very similar to the Oechelhäuser engine described below.

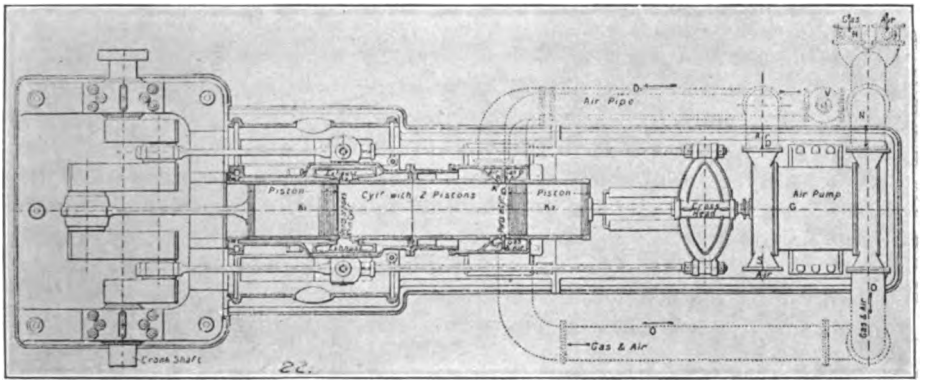
Oechelhäueser (1896).

The demand for large power engines, and the application of blast-furnace and coke-oven gases to drive them, have brought this striking motor to the front. In some respects it resembles the first Atkinson engine, known as the Differential. The latter had not an air pump, like the Oechelhäueser, but in both motors, valve gear is practically dispensed with. As hitherto made, the Oechelhäueser has one long cylinder open at both ends, with two pistons, performing between them the functions of admission and compression of the charge, and discharge of the exhaust gases. There is no cam shaft, and the valves usually driven by it are replaced by ports uncovered and shut off by the motor pistons during their stroke. These pistons work in the horizontal cylinder in opposite directions on to the same crank shaft, through three cranks 180° apart. The two outer cranks are connected by rods and crossheads with a cross piece at the back of the cylinder, through which the piston of the back cylinder works. The double-acting pump on the same axis as the motor cylinder is at the back of the cross-piece, and its piston is driven from it.

Fig. 22 gives a plan of the engine, and illustrates the action. G is the air pump, K_1 and K_2 the two motor pistons. Beginning with the point in the stroke, where the two pistons are almost close together, the charge of gas and air between them is compressed within very small limits to a pressure of 8 or 10 pounds above atmospheric pressure. Electric ignition follows, and the two pistons are driven apart by the pressure of explosion, which is in proportion to the heating value of the gas used, and sometimes reaches 355 lbs. per square inch (25 atmospheres). Work is thus done by

Digitized by Google

both pistons on the crank (double motor stroke). Meanwhile the piston of the air pump G has drawn in fresh air through the automatic valve S, and the return stroke of this piston compresses it on its front face, and passes it at a slight pressure through D and the air chamber R into the compression space. On the back face of this piston another series of operations are simultaneously carried out. Here a mixture of gas and air is drawn in through another automatic valve N, and compressed by the pump piston through o into the mixing chamber P, which it enters at the same pressure as the air in R. Piston K_1 having passed the outer dead point of the center crank, now begins to uncover the exhaust ports C_1, and the products of combustion are driven out. Piston K_2 next uncovers the air port A, and the air under pressure rushes from R into the motor cylinder, sweeping out the



OECHELHANSER 2-CYCLE ENGINE.

burnt products before it, and forming an effective scavenger charge. The admission port Q is then uncovered by piston K_2 and the charge of gas and air, compressed to about 7 lbs. per square inch, enter the motor cylinder. The makers of the engine assert that none of this fresh charge escapes through the exhaust with the scavenger blast of air, because the volume of the cylinder is so proportioned that, even when running at maximum load and power, the charge only occupies about 70 per cent of it. Both motor pistons now begin the return stroke, the mixture is compressed between them, and the cycle recommences.

If there are only slight variations in the speed, the governor acts upon the relative proportions of gas and air, and alters the composition of the charge; if the speed is varied within wider limits, it regulates the quantity of the charge through the mixing valve cock H and the return slide valve V in the passage D. Part of the compressed charge passes from o into the suction pipe N, and is thence transferred to the other side of the pump, instead of passing, as usual, to the motor cylinder. In the latest system type, the governor acts separately upon the admission of gas and of air.

In this interesting engine compression, ignition, and expansion of the charge occupy respectively seven-eights of the stroke, while admission and exhaust are effected during the remaining one-eighth of each stroke. Fig.

Digitized by Google

23 shows an indicator diagram; the exhaust opens at a, and at c compression of the gases up to 140 lbs. per square inch begins. An unusual feature is that water is sprayed onto the exhaust gases to cool them. The latest engines are fitted with two electric igniters. In some motors, gas alone enters through the admission ports, and the charge is formed in the motor cylinder itself; this arrangement depends upon the kind of gas used.

The advantages of the Oechelhäeser cycle are that a motor stroke is obtained at each revolution instead of at every other revolution, and as this is effected by two working pistons, the power is said to be increased four-fold. The necessity for two cylinders, motor and pump, does not cause difficulty, because for large powers two cylinders are practically indispensable. Admission and exhaust are effected in one stroke instead of in two and the cylinder dimensions are smaller for the same power than in the four-cycle type. Thus a 1,000 H. P. single-cylinder Oechelhäueser engine has a cylinder diameter of only 26.8 inches = 935 mm. For work with poor gases, the simplicity of the long smooth cylinder, without the complication of a cylinder head and valve chest, and the absence of valves are also advantages, because dust cannot settle in the working parts. The only external gear required is a small auxiliary shaft to drive the governor, igniters, and the starting valve. When used for blast-furnace work, the blowing engines can, it is said, be driven direct from the motor piston without a stuffing-box, and can themselves be utilized, as at Hörde, to supply the scavenging charge of air. On the other hand, the engine has three cranks and three connecting rods and two pistons, and the connections are somewhat complicated. The governing at first was said not to act efficiently, but this has now been remedied.

The mechanical efficiency of these engines was about 80% and the econ. efficiency as high as 28%.

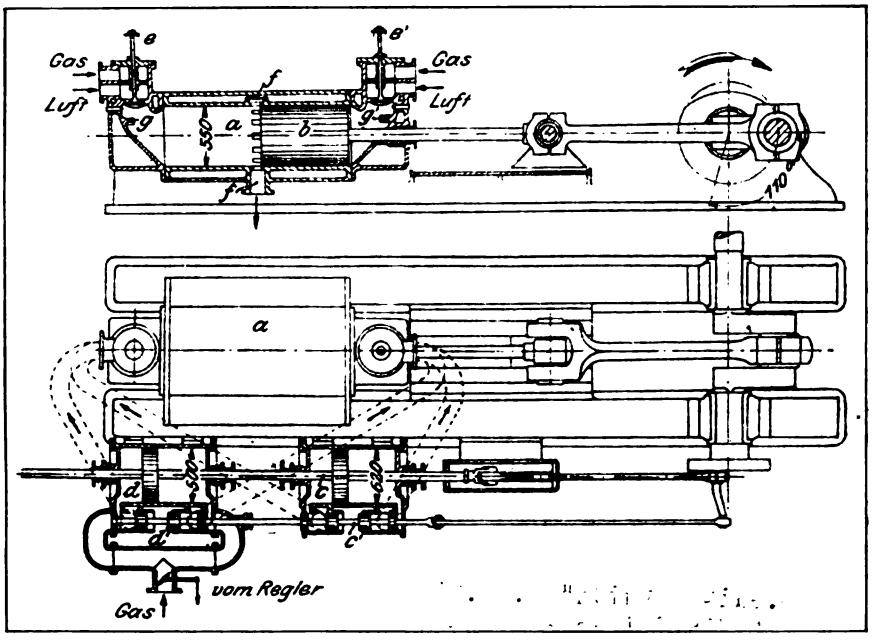
Körting.

Messrs. Körting designed many engines, the first of which were built in 1882. Later (1898) this firm was very active in the development of large double-acting two-cycle engines and their product is today one of the best known in Europe. The manufacture is carried on in this country by the De La Vergne Machine Co., of New York, who have installed plants with a capacity of 42,000 H. P. (See Journal A. S. M. E., 1910), pages 1361-1466.

The Körting engine described below is of the two-cycle double-acting type. (Fig. 24.) The water cooled piston (b), the length of which is about 7/8 of the stroke, moves in the main cylinder (a). A small crank, about 110° ahead of the main crank, operates the air pump (c) and the gas pump (d). The latter are controlled by the piston valves (c′) and (d′). Mixing of gas and air occurs in the housing of the intake valve (e). Both sides of the cylinder discharge into the common exhaust port (f), which is alternately opened to the crank and head ends of the cylinder by the movement of the piston. When the exhaust ports are uncovered, the pump pistons have completed about half their stroke. Up to this time, the intake channel of the pump (d) remains open, and so about 40% of the gas drawn in during the previous stroke is expelled back into the supply pipes. Now the valve

Digitized by Google

(d') closes this channel and opens the discharge channel, which allows the rest of the gas to enter the engine cylinder. Just before this occurs a charge of air has been admitted to scavenge the cylinder. The scavenging and intake continue until the pump is at the end of its stroke, which is just the time when the returning piston covers the port (f). The enclosed charge is compressed to 10-12 atmospheres and exploded by two electric igniters. Two are used to insure a reliable ignition and a more efficient flame propagation. In the first engines the speed was regulated by throttling the gas, but this



KORTUNG ENGINE.

caused a great loss in the pump when running under light load, and so in later engines the governor controlled the intake valve of the gas pump (d), so that under light loads a larger part of the gas is expelled back into the supply pipes. Baffle plates (g) are provided to prevent the incoming charge from escaping through the exhaust ports (f).

The economical efficiency n_w of these engines was very good, running from 17 to 24%. Mechanical efficiency 62% to 71%.

(To be Continued.)

Digitized by Google

INVENTIVE GENIUS AND COMMERCIALISM

L. J. WATSON

It has been said that inventive genius always rises to meet the demands placed upon it. It can be said, too, that there is invariably an element of commercialism which rises to oppose and suppress the work of the inventor, notwithstanding the common belief that manufacturers are always ready and anxious to take hold of improvements in their line which have been proven of intrinsic value.

Every inventor is likely to get the idea, before he goes far, that he is a victim of an unjust and galling commercial restraint. Whether he is, or whether he is not, there are two sides to the question, which all fair minded persons will admit, and which no one can truthfully deny.

Admitting that the great majority of inventors can be expected to attach exaggerated importance to, and over-estimate the value of, their alledged improvements, and further admitting that some so-called improvements are impractical or are not improvements at all, there are a few that are decided improvements, and it is in behalf of these few that this paper has been written.

These few have to forego the opposition of the people, some of which are uninformed in the line to which the invention pertains and, as a result, are skeptical, and others who do understand and can see in it a commercial competition which they fear, and which they may seek to destroy by any available means.

Taking up one side of the question, of which we have said there were two sides, it is easy to see that any new and useful improvement is sure to threaten the market of some other similar device of established use, the demand for which must naturally fall off in proportion as a demand for the improved article may grow.

Naturally, then, the manufacturers and promoters of the old staples join in opposition, and try to discourage any improved device which tends to detract from their established business, and every argument in their favor is made use of by them to hold their existing trade and to smother the new invention. They will say their goods meet every requirement of the business, as demonstrated by the general satisfaction they are giving their customers.

Their customers by the way seldom know of the improvement and do not appreciate its advantages. They have become reconciled to the old way of doing things, no matter how primitive they may be—in other words, their contentment is mainly due to their supposition that what they have is the best there is to be had.

After the new article has been introduced in the market (should the inventor succeed to this extent) they point to the risk of buying a device in the experimental stages; the confusion and expense which changes always entail; the added variety of repairs that it will be necessary for the middle-man to carry in stock, etc., etc. If, after having made use of every truthful argument, they find the new invention still advancing, they may then be expected to resort to underhanded methods, and use sheer force, if they are in position to do so, to crush out the life of the newly launched enterprise.

This is especially true if the new

Digitized by Google

invention is an appliance or fixture that is bought by one manufacturer, from another, to sell with his machine as a whole to the consumer, the man who buys the machine and wears it out In this case it is plain to be seen that the manufacturer of the large machine, who buys the fixture of some other concern to equip his machine with, is prone to use that which is cheapest just as long as said cheap fixture will be accepted by the general trade.

If the prospective purchaser is not aware of the better fixture, they aim and hope to keep him in the dark if possible, and if he learns about it they do not hesitate to belittle and condemn it in every way.

No matter how much better for the user the improved fixture may be, they will not use it at a greater cost until forced by their patrons to do so. Instances are recorded where Patent Rights to new inventions of merit have been bought by manufacturers and corporations at very attractive prices, only to be pigeon-holed and kept from interfering with their standard and staple old-fashioned methods and devices. Naturally, less expensive means will be first resorted to.

For the manufacturer of any machine to decline or refuse to install improvements, or to adopt an improved fixture for their machines because said fixture costs a little more than the old-style one they may have been using for years, would, in the opinion of the writer, be following a narrow-minded and manifestly very selfish policy, a policy which bids fair to defeat their very purpose of doing it, which, it is safe to assume, is to increase the profits to be derived from their business. Of course it may mean a present saving, and consequent increase in profits for them; but the future must be considered if they expect to successfully remain in their old line of business.

It would show, too, that they were overlooking the best interests of their customers; and when they become so selfish that they have little or no regard for the welfare of others, especially those to whom they must look for their own future success, it would seem they must either expect to soon be going out of business in their present line, or that they considered their customers a class who were not capable of appreciating fair treatment, or were not shrewd enough to learn that their confidence in them was being betrayed.

It has been said that "sometimes the best way to make money is to spend it well."

It is certainly as possible to economize to unprofitable extremes as it is to lose by extravagance.

Selfishness is a weed, which thrives most in the soil of narrow-mindedness.

The fruit of narrow-minded selfishness was once impressively revealed to me by an experience I had when a boy on a farm: Father had begun feeding his hogs for the Fall fattening, although they had not yet been penned up and had liberty to pasture in two adjoining fields The gate through which they passed from one field to the other was about midway between the ends of the fence dividing them, and about twenty rods from the corner of the field in which the feeding was done.

I threw out a feed of corn and called the hogs, which were browsing in various places about the opposite field. Each started for the feeding place—some by way of the gate and, a few, which were near the same side of the field as the feeding-place, took a bee-

Digitized by Google

line course for it, coming up to the corner, but, on the wrong side of the fence.

There they stood, looking through the fence and squealing while the others had their meal, and they had their appetites whetted. With their superabundance of greed and their narrow-mindedness, they could not reason out that the way to get at the object of their desires was to first run away from it.

In this regard they might be likened to the manufacturers of machinery who decline to make needed improvements to their goods because to do so would add a little to the initial cost.

Manufacturers of machinery who take the initial steps in adopting time and labor saving devices, or those of greater efficiency, certainly deserve the respect of the people who use them; and, other conditions being equal, will generally win and hold their patronage.

In a talk I had not long ago with a man of over twenty years' successful record as a machinery salesman and collector in an extended district, he told me there were a few, who, in purchasing machinery, wanted something cheap; the matter of quality not concerning them materially so long as the machine would do fairly satisfactory work.

The majority, however, he stated, preferred the goods of better quality and were willing to pay the difference in cost to get them. It was necessary, though, to make it clear to them wherein the greater value lay.

He further stated that it was a grave mistake for any to misrepresent their goods, in any way, in order to sell them; that honesty, and a square deal, were the best policies. His views, at least, corroborate my own.

In commercialism these policies are not always followed. With it, too often, might is right; and under the compelling circumstances of this order of things, truth and merit frequently go begging.

I have said that I believed in honesty and the square deal; therefore, in keeping with this policy, it behooves me to admit here that what has been said in the foregoing represents but one of the two sides of the case—the dark side, as it may be expressed.

Looking at the case on the other or bright side it must be admitted that all progress that has been made—which during the past fifty years has been truly mervellous—has been due to commercialism that has aided inventive genius.

It is better to be an optimist than a pessimist, but it certainly is not in keeping with optimism to overlook or to cover up knowledge for commercial reasons.

Digitized by Google

AN APPROXIMATE NUMERICAL SOLUTION OF DIFFERENTIAL EQUATIONS IN TWO VARIABLES

PROF. T. R. RUNNING

The following approximate solution of differential equations depends upon the principle of areas. Simply stated the solution is derived from the fact that the difference between any two ordinates of a curve is equal to the area under the derived curve included between the corresponding ordinates. Geometrically this is illustrated in figure 1. The shaded areas are segments of the integral and derived curves over the range included between x_0, the initial value of the independent variable, and x, some other value greater than x_0. The chord of the arc must not be over one and one-half units or at most two units; ordinarily a fractional part of a unit. If $\gamma - \alpha$ is a small angle, as will be explained later, the chord may be taken greater than a unit.

From figure 1 it is readily seen that the following equations are true:

$$\int_{x_0}^{x} y'\,dx = y - y_0$$

$$\int_{x_0}^{x} y''\,dx = y' - y_0'$$

$$\int_{x_0}^{x} y'''\,dx = y'' - y_0''$$

$$\int_{x_0}^{x} y''''\,dx = y''' - y_0'''$$

$$\int_{x_0}^{x} y'''''\,dx = y'''' - y_0''''$$

where

$$y' = \frac{dy}{dx_1} \qquad y'' = \frac{d^2y}{dx^2} \quad etc.$$

x_0 is the initial value of x and the subscript zero is used with y and its derivations to indicate their corresponding values.

Suppose that we have a differential equation of the fifth order and suppose that the integral and derived curves have the relation indicated in figure 1 between the values of the independent variable x_0 and x. Let A_n stand for the area of the triangle formed by tangents at the extremities of the arc and the chord of the curve dy^n/dx^n. The area of the segment will be less than the area of the triangle provided the arc does not include a cusp or a point of inflection. Let the ratio of the area of the segment to the area

Digitized by Google

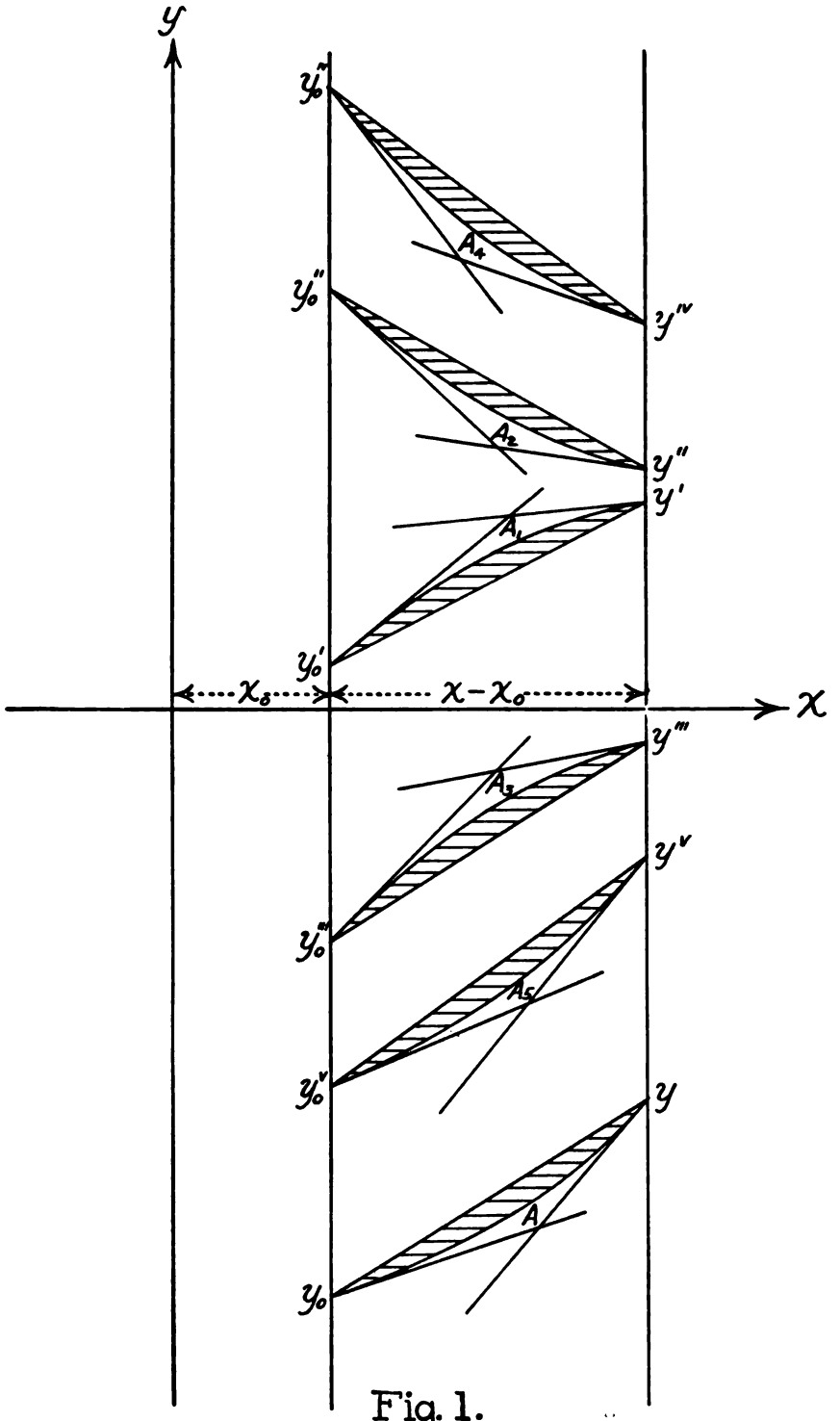


Fig. 1.

Digitized by Google

of the triangle be represented by K_n. With these agreements the following equations hold:

(1)

$$\frac{y_0' + y'}{2}(x - x_0) + K_1A_1 = y - y_0$$

$$\frac{y_0'' + y''}{2}(x - x_0) + K_2A_2 = y' - y_0'$$

$$\frac{y_0''' + y'''}{2}(x - x_0) + K_3A_3 = y'' - y_0''$$

$$\frac{y_0'''' + y''''}{2}(x - x_0) + K_4A_4 = y''' - y_0'''$$

$$\frac{y_0''''' + y'''''}{2}(x - x_0) + K_5A_5 = y'''' - y_0''''$$

The plus sign has been used before each term representing the area of a segment, because, as will be seen later, the function which represents the area of the triangle in each case will carry with it the proper sign.

If the different values of K and A were known we would have a set of five equations together with the given differential equation from which the values of y, y', y'', y''', y'''', and y''''' could be computed. These values would again form a new set of known values which could be used in exactly the same way to determine another set corresponding to a selected value of the independent variable. It is to be observed that the equations in set (1) are linear in the unknown quantities.

The first step in the process of solution will then be to determine expressions for the values of K and A. From figure 2 the area of the triangle represented by A_1 is equal to the right triangle ABD minus the right triangle CBD.

$$\begin{aligned} A &= \tfrac{1}{2}(x - x_0)^2 \sec^2\beta \sin(\alpha - \beta)\cos(\alpha - \beta) - \tfrac{1}{2}(x - x_0)^2 \sec^2\beta \sin^2(\alpha - \beta)\cos(\alpha - \gamma) \\ &= \tfrac{1}{2}(x - x_0)^2 \sec^2\beta \sin(\alpha - \beta) \frac{\sin(\alpha - \gamma)\cos(\alpha - \beta) - \sin(\alpha - \beta)\cos(\alpha - \gamma)}{\sin(\alpha - \gamma)} \\ &= \tfrac{1}{2}(x - x_0)^2 \sec^2\beta \sin(\alpha - \beta) \frac{\sin(\beta - \gamma)}{\sin(\alpha - \gamma)} \\ &= \tfrac{1}{2}(x - x_0)^2 \sec^2\beta \frac{(\sin\alpha\cos\beta - \cos\alpha\sin\beta)(\sin\beta\cos\gamma - \cos\beta\sin\gamma)}{\sin\alpha\cos\gamma - \cos\alpha\sin\gamma} \end{aligned}$$

Dividing numerator and denominator of the fraction by $\cos\alpha\cos\gamma$ we have

$$\begin{aligned} A &= \tfrac{1}{2}(x - x_0)^2 \sec^2\beta \frac{(\tan\alpha - \tan\beta)(\tan\beta - \tan\gamma)\cos^2\beta}{\tan\alpha - \tan\gamma} \\ &= \tfrac{1}{2}(x - x_0) \frac{(\tan\alpha - \tan\beta)(\tan\beta - \tan\gamma)}{\tan\alpha - \tan\gamma} \end{aligned}$$

Consider the triangle A_1 in figure 1. Since $\tan\beta$ is less than $\tan\alpha$ and $\tan\gamma$ less than $\tan\beta$ the expression representing its area is positive and therefore K_1A_1 will be positive. It is seen from the figure that the area of the segment must be added to that of the trapezoid to make the first equation in set (1) true. In the case of A_2 the conditions are different: $\tan\alpha$ is less than $\tan\beta$ and $\tan\gamma$ less than $\tan\beta$. The expression representing the area of this segment will, therefore, be negative, and it is seen that the area

Digitized by Google

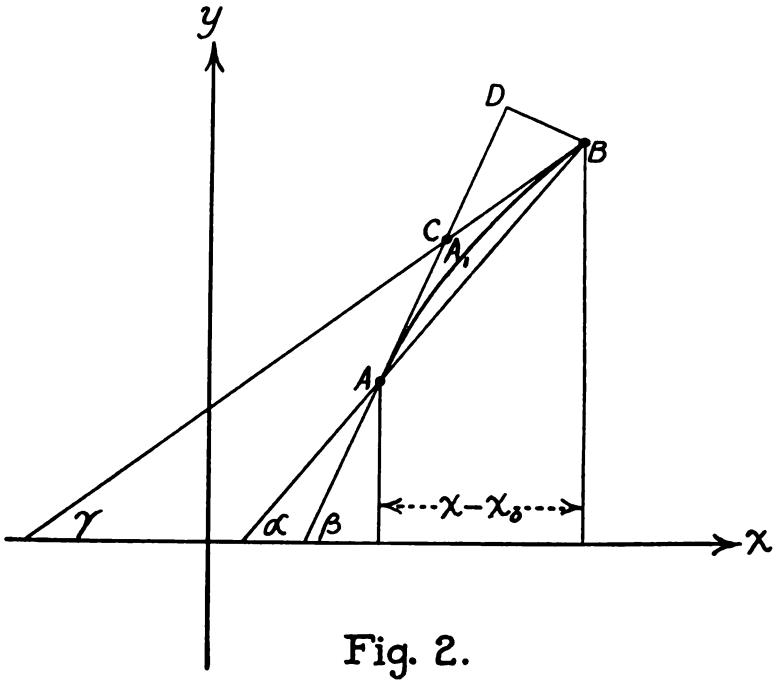


Fig. 2.

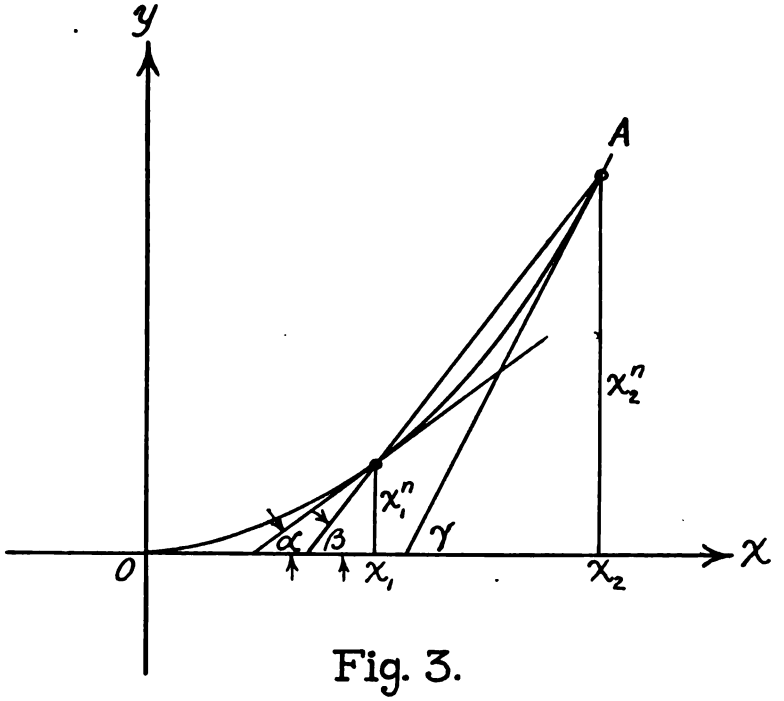


Fig. 3.

Digitized by Google

must be subtracted from that of the trapezoid in order that the second equation of (1) may be true without discussing each of the expressions representing the areas of the segments it is evident from what has been said that the sign belonging to each of the second terms in the left hand members of the equations of (1) is determined by the expressions themselves.

If the correct values of K and A could be obtained the exact numerical values of y and its derivatives would be found by solving set (1) and the given differential equation. In the nature of the case this is impossible for their values, necessarily, depend upon the soultion of the differential equation. An approximate value K can, however, be obtained which will enable us to find a close approximation to the solution of the differential equation.

For the purpose of obtaining an expression for K we will first find the limit which K approaches as the arc of the segment approaches zero as a limit in the curve

$$y = x^n.$$

In figure 3, OA represents an arc of this curve.

$$\frac{dy}{dx} = n\,x^{n-1}$$

$$\tan\alpha = n\,x_1^{n-1}$$

$$\tan\gamma = n\,x_2^{n-1}$$

$$\tan\beta = \frac{x_1^n - x_1^n}{x_1 - x_1}$$

$$\tan\alpha - \tan\beta = n\,x_1^{n-1} - \frac{x_2^n - x_1^n}{x_2 - x_1}$$

$$\tan\beta - \tan\gamma = \frac{x_2^n - x_1^n}{x_2 - x_1} - n\,x_2^{n-1}$$

$$\tan\alpha - \tan\gamma = n(x_1 - x_2^{n-1})$$

The area of the triangle becomes

$$\tfrac{1}{2}\,\frac{[n\,x_1^{n-1}(x_2 - x_1) - x_2^n + x_1^n]\,[x_2^n - x_1^n - nx_2^{n-1}(x_2 - x_1)]}{n(x_1^{n-1} - x_2^{n-1})}$$

The area of the segment is

$$\frac{x_2^n + x_1^n}{2}(x_2 - x_2) - \int_{x_1}^{x_2} x^n dx$$

$$= \frac{(n+1)\,(x_2 - x_1)\,(x_2^n + x_1^n) - 2x_2^{n+1} + 2x_1^{n-1}}{2(n+1)}$$

$$K = -\frac{[(n+1)\,(x_2 - x_1)\,(x_2^n + x_1^n) - 2x_2^{n+1} + 2x_1^{n+1}]\,[x_1^{n-1} - x_2^{n-1}]\,n}{(n+1)\,[nx_1^{n-1}(x_2 - x_1) - x_2^n + x_1^n]\,[x_2^n - x_1^n - nx_2^{n-1}(x_2 - x_1)]}$$

The minus sign being used in order to make K positive.

This expression becomes indeterminate as x_2 approaches x_1. Evaluating it we find that it approaches $2/3$ as a limit, provided that x_1 is not zero. If x_1 is zero the value of the expression for all values of x_2 is $n/(n+1)$. The conclusion to be drawn from this fact is that when the end of the arc is located at a point of inflexion K must be taken as $n/(n+1)$. For short arcs and small values of $\gamma - \alpha$ K taken as $2/3$ will give fairly good results provided that at a point of inflexion the value be taken as $3/4$. But as it is incon-

Digitized by Google

venient to proceed by short steps it is far better to have an expression for K which will yield good results for larger values of the arc and $\gamma - \alpha$.

A fairly close approximation to the value of K found by a rather tedious process is

$$K = \tfrac{2}{3} + \frac{D^{1.6}\, L^{.6}}{21550}$$

where $D = |\gamma - \alpha|$ in degrees and L is the length of the chord.

On account of the probability of error in computing K from this formula it is desirable to replace it by a much simpler one and one which will give nearly as good results. When $\gamma - \alpha$ has a value from 0° to 10° K may be taken equal to $2/3$, and when $\gamma - \alpha$ lies between 10° and 25° the value may be taken equal to .67. In applying the above rule the chord should not be over one and one-half units for the larger values of $\gamma - \alpha$.

In what follows it is assumed that an arc of the curve $y = x^n$ can be found which will fit closely any arc of the integral or derived curves under consideration. For an arc whose extremity is located at a point of inflexion the value of K must be determined in each case; that is, the best value of n in the formula $K = n/(n+1)$. To avoid this determination of n it is safe to assume that a short arc of $y = x^3$ extending from the point of inflexion will fit the curve in which case K may be taken to be $\frac{3}{4}$ as stated above.

The separate steps in the computation are best set forth by an illustration. Let us solve the equation of the second order

$$x^2y'' + xy' - (x^2 + \tfrac{1}{2})y = 0.$$

for values lying between $x = 1$ and $x = 3$. We start from a set of assumed values corresponding to $x = 1$

$$y = 1$$
$$y' = .5$$

The equation then gives us

$$y'' = .75$$
$$y''' = -.125$$

The solution of the above equation will make clear the steps necessary in the solution of an equation of any order.

The computation for finding the values of y and its derivatives corresing to $x = 12$ will be propounded in detail.

For the first approximation

$$\frac{y'' + .75}{2} .1/5 = y' - .5$$

$$\frac{y' + .5}{2} .1/5 = y - 1$$

As α, β, and γ are unknown the terms containing K are left out.

$$y'' = 100\, y - 110.75$$
$$y' = 10\, y - 10.5$$

Substituting these values in the differential equation we have

$$154.31\, y = 172.08$$
$$y = 1.1151578$$

first approximation. The corresponding values of y'' and y' are obtained by substituting the value of y just found in equations (1) and (2) respect-

Digitized by Google

TABLE

x	y	y'	y''	y'''	Correct value of y	y'				y''			
						$\tan\alpha$	$\tan\beta$	$\tan\gamma$	k	$\tan\alpha$	$\tan\beta$	$\tan\gamma$	k
1.0	1.	0.5	0.75	−0.125	1.								
1.2	1.1151578	0.651578	0.765780	0.256361		0.75	0.75789	0.76578	2/3	−0.125	0.0789	0.25636	0.67
	1.1149853	0.650378	0.766506	0.253684	1.114983								
1.5	1.3475350	0.899953	0.897316	0.602717		0.766506	0.831910	0.897316	2/3	0.253684	0.436030	0.602717	0.67
	1.3461643	0.897354	0.897500	0.598122		0.766506	0.823251	0.897500	2/3	0.253684	0.436647	0.598122	0.67
	1.3461864	0.897458	0.897499	0.598222	1.346175								
2.0	1.9340070	1.453825	1.327970	1.123285		0.897499	1.112735	1.327970	0.67	0.598222	0.860942	1.123285	0.67
	1.9218322	1.441178	1.321358	1.110753		0.897499	1.087441	1.321358	0.67	0.598222	0.847717	1.110753	0.67
	1.9221445	1.441491	1.321529	1.111063		0.897499	1.088067	1.321529	0.67	0.598222	0.848060	1.111063	0.67
	1.9221343	1.441483	1.321525	1.111053	1.922116								
2.5	2.8538373	2.285329	2.053859	1.829528		1.321525	1.687696	2.053859	0.67	1.111053	1.464668	1.829528	0.67
	2.8339085	2.266946	2.040486	1.813456		1.321525	1.650927	2.040486	0.67	1.111053	1.437922	1.813456	0.67
	2.8344154	2.267433	2.040819	1.813891	2.834468								
3.0	4.2970606	3.583148	3.222041	2.927182		2.040819	2.631430	3.222041	2/3	1.813891	2.362444	2.927182	2/3
	4.2652121	3.554189	3.198961	2.902521		2.040819	2.573513	3.198961	2/3	1.813891	2.316284	2.902521	2/3
	4.2660450	3.554981	3.199553	2.903210	4.266073								

Digitized by Google

ively. y''' is obtained by substituting the above values in the equation obtained by differentiating the given equation. These values are copied in the table below.

The last two divisions of the table headed y' and y'' refer to the first and second derived curves respectively. The values of tan α, tan β, and tan γ are taken from the first part of the table. In the part of the table headed y' tan α is equal to the value of y'' for $x = 1$, tan γ is equal to the value of y'' for $x = 1.2$, and tan β is obtained by taking the difference between the two values of y' corresponding to $x = 1$ and $x = 1.2$ and dividing by 1/5. The values of K used in the table were determined by the last method.

The equations for the second approximation are

$$\frac{y'' + .75}{2} \cdot 1/5 - 1/2\ 67/100 \cdot 1/25 \frac{(.2039)\ (.17746)}{.38139} = y' - .5 \text{ and}$$

$$\frac{y' + .5}{2} \cdot 1/5 - 1/2 \cdot 2/3 \cdot 1/25 \frac{(.00789)(.00789)}{.01578} = y - 1$$

$$y'' = 100\,y - 110.732036$$
$$y' = 10\,y - 10.499474$$

Substituting these values in the differential equation we find that

$$y = 1.1149853$$

y', y'', and y''' are found as before.

For finding the values of y, y', y'', and y''' corresponding to $x = 1.5$ the above process is repeated.

In the sixth column the correct values of y to six decimal places are given for the purpose of comparison.

In finding the values of y and its derivatives corresponding to $x = 1.2$ only two approximations were made, a third being unnecessary because the two differed only slightly in the fourth place. For values corresponding to $x = 2$ four approximations were made because the second and third differed by three units in the fourth pace. For the same reason a fourth approximation should have been made in the last two steps. The results would have been changed slightly in the fifth decimal place.

Digitized by Google

COMBINED COURSE WITH ALBION COLLEGE

The committees representing Albion College and the Engineering Department of the University of Michigan met at Albion College on October 17th, 1914, to discuss the final details as to the arrangement of work in the combined course, the principle of which had already been sanctioned by the Board of Regents of the University at their October meeting.

In general, it is proposed that a student shall spend at least three years at Albion College and two succeeding years at the University. At the end of his first year's work at the University, provided the reports are satisfactory, he will receive the degree of Bachelor of Arts from Albion Colleeg; the latter Institution being willing to accept the work done at the University as the equivalent for the fourth year.

Upon the completion of the requirements for graduation in the Engineering Department, the student will receive the degree of Bachelor of Science in Engineering.

The work performed at Albion College will be of such character and extent as to enable the student on the combined course to enter the third year of the regular engineering courses at the University. To accomplish this end certain work which normally comes in the *third* year in some of the engineering courses, will be given at Albion College in order that the student may not be handicapped by having to make up certain other courses, facilities for the teaching of which are not available at Albion College, and which normally come in the *second* year of the engineering course. Part of the shop requirements will be made in Albion factories.

A schedule of work for the first three years at Albion College is attached hereto, and represents in general the arrangement of work for the various branches of engineering which the combined committees recommend for adoption.

In making the above schedule certain facts were kept in mind. Although Albion College requires the same number of units for entrance as the University, it does not insist upon Physics, Chemistry, or three units of Mathematics (two only being required). The result is that it is necessary to devote sufficient time to these subjects, so that the student, at the end of his three years, will have covered the work necessary to enable him to enter the third year of the engineering course. This encroaches somewhat upon the time available for the more general cultural courses, but it should be borne in mind that in nearly all cases the student will have presented for entrance more work of this character than that required by the Engineering Department.

PROPOSED COURSES.

FIRST YEAR.

First Semester.

	hours
German or French	5 or 4
English I	3
College Algebra	4
General Physics	3
Descriptive Geometry	2

Second Semester.

	hours
German or French	5 or 4
English I	3
Trigonometry	4
General Physics	3
Descriptive Geometry	2

Digitized by Google

SECOND YEAR.

First Semester.

German or French	4
English II	2
General Chemistry	4
Analytic Geometry	4
Laboratory Electricity	2

Second Semester.

	hours
German or French	4
English II	2
Qualitative Analysis	4
Calculus	4
Laboratory Electricity	2

THIRD YEAR.

First Semester.

	hours
Mechanics	3
Advanced Physics	3
Advanced Analytics & Calculus	4
Electives	6 or 7

Second Semester.

	hours
Mechanics	2
Advanced Physics	3
Advanced Calculus	4
Electives	7 or 8

Electives.

In Civil Engineering—Geology (3 hrs. each semester), Cultural (3 or 4 hrs. each semester).

In Mechanical and Marine Engineering—Surveying (2 hrs.), Machine drawing (2 hrs.), Metallurgy (2 hrs.), Cultural Electives (3 or 4 hrs. each semester).

In Electrical Engineering—Surveying (2 hrs.), Machine drawing (2 hrs.), Metallurgy (2 hrs.), Cultural Electives (2 hrs.), Electrical Measurements (3 hrs. each semester).

In Chemical Engineering — Quantitative Analysis (4 hrs. each semester), Mineralogy (3 hrs.), Machine drawing (2 hrs.), Metallurgy (2 hrs).

The Committee for the Engineering Department of the University of Michigan consisted of H. C. Sadler, Chairman, W. C. Hoad, Alexander Ziwet, A. H White, and G. W. Patterson. The Committee for Albion Colleeg consisted of C. W. Greene, F. W. Douglas, E. R. Sleight and Delos Fall.

Digitized by Google

ADDRESS BEFORE FRESHMEN CLASS

HON. LAWTON T. HEMANS*

"Dean Cooley, with a sincere purpose of compliment, has told you that I was once the candidate of the Democratic party for Governor. That you may draw no false conclusions, perhaps I should tell you the whole truth, —that I have been a candidate not once, but twice; that running for Governor has become somewhat of a habit with me. Once upon a time in my first campaign, at the conclusion of an address a man came up to the platform and put up a hand that indicated its possessor was familiar with physical toil, and said—"Mr. Hemans, I want to shake your hand and tell you that you will at least get every Democratic vote in my township. I am the only gol durned Democrat there;"—so you see running for Governor on the Democratic ticket in Michigan may indicate no quality greater than courage in the candidate.

It is a matter of exceptional pleasure to view so large a body of young men and women on the threshold, so to speak, of engineering careers, for while most of us no doubt are looking forward to the financial and material rewards that are to come from professional effort, there is another side which to my mind is of equal, if not greater import, both to you as individuals and to society as a whole.

It is a matter of frequent comment that this is an age of wonderful development, but in no field is it more true than in the field of the so-called public utility. Our great railway systems, illuminating gas from destructive distillation, water under pressure, light, heat and power from electric energy, the telephone and the telegraph are the product of the inventive genius of little more than a life-time. The public utility has almost transformed our civilization and has become one of the greatest of our social and economic problems.

With the introduction of the first utilities, nothing was more natural than that they should have been left to the individual creation and control of the interests which promoted them, but society very soon learned that the business of the utility, whether it was in the furnishing of transportation, in the transmission of intelligence, or in the furnishing of water, light, heat and power, had characteristics which made it fundamentally different from the ordinary business, which individuals had prosecuted for all the centuries of the past. In the business of the ordinary merchant there is an appeal to a variety of tastes and the financial ability of the purchaser, which invite competition. This is a characteristic wholly lacking in the product of the public utility. The very nature of the service which public utilities render removes them from the field where efficiency and economic considerations are promoted by competition. In other words, public utilities are natural monopolies. Because they are monopolies serving the public, they cannot safely be entrusted to private control. We have then the two alternatives: Governmental or political ownership and control, — or private ownership and governmental supervision and control. The issue between these two systems is of tremendous importance.

The Michigan Railroad Commission, as you know, passes upon the

* Chairman of Michigan Railroad Commission.

Digitized by Google

stock and bond issues of all public service corporations. During the past four years, for the public utilities of the state, and for the railways that cross its borders, it has authorized stock and bonds to the amount of between six and seven hundred millions. This enormous sum is needed simply to keep pace with the growth of our commonwealth. Shall the institutions which expend these vast sums become a part of our political machinery, or shall they be left as a part of industrial activities of society, with unrestricted power in government to investigate, regulate and control?

It seems to me that before governmental ownership and control can be effectively urged, it must be demonstrated that political activities are superior to those found in the business world. They should show that our cities are run more efficiently and economically than our vast industrial institutions, which is notoriously not the case. We all know that the power to successfully manage and administer is superior to the power to create. There are a thousand men who have the power to conceive an enterprise, where there is one that has the ability to conduct it to successful issue. We cannot have the impetus of individual desire to achieve in the lines of public utility, if as soon as the utility is created it is to become a function of government, and we have not come to the end of our public utility creations.

Our own government was founded on the idea of developing the individuality of each citizen, providing the greatest scope for the exercise of his abilities and powers.

All of these considerations point to private ownership and governmental control as the solution of the great problem of the public utility. It gives free exercise to the individual intiative. It restricts opportunity only by the ability of he who survives. It gives the public the benefit of the superior thrift, energy and capacity of individual business, while it preserves to the public the power to regulate, restrict and supervise, necessary to protect the public interest.

But efficient supervision and control necessitates t h o r o u g h and exact knowledge, and it is here that society looks to the men of the profession upon which you have entered. That the regulating body may properly prescribe the rate of return and the quality of service, it must have extensive knowledge as to original cost, as to depreciation, current maintenance, as well as many other elements that enter into a proper adjustment of the rate. Many of these elements are still unknown with anything like definiteness by even the men who promote the enterprise.

So large a body of young men and women as I see here before me must be an important factor in the solving of the problems presented and it is here that your greatest work is to be accomplished. You will go from here to achieve the material and financial successes that are always an important consideration, but the greater success will be in the service which you will contribute to society and to government through high, lofty and disinterested effort in the solution of one of this state and nation's greatest problems. With these things in mind I cannot do otherwise than congratulate you upon the auspicious field that lies before you.

Perhaps I should say to you in conclusion that this is a very happy day to me individually,—for fifty years ago today two very important events occurred, — Abraham L i n c o l n was elected to the Presidency, and I was born.

Digitized by Google

MECHANICAL ENGINEERING SPRING TRIP

PROF. J. R. ALLEN

The spring trip for the Mechanical engineers was originally planned by Dean M. E. Cooley and was first taken in 1888. Since that time similar trips have been taken almost every year. In recent years, however, the real purpose of the trip seems to have been lost sight of. The trip was primarily planned for students in their junior year so that they might better appreciate the work of the senior year. It is not until the senior year that the students come into contact with the more practical side of engineering. Most students are lacking in sufficient knowledge of manufacturing processes and of the operations of the great factories and power houses. The intention of the trip is to supply this lack of information and to give the students a better appreciation of what our great manufacturing institutions are and what their future place in these institutions may be.

The trips are so arranged that the students visit as many different manufacturing operations as possible and as many different typical power houses as it is possible to do in the limited time. The experience of students who have taken the trip in former years has shown that these trips are extremely valuable and materially help the student in his senior year to properly comprehend his work. In fact, the trip is one never to be forgotten as the student is enabled to visit many of the manufacturing establishments that would be impossible were he to attempt to obtain permission to see them alone. In order to obtain permission to go through some of the establishments visited it is necessary to have the action of the board of direction of the company as these plants are equipped with special apparatus and have special processes to which the public are not generally admitted. Many students have said after taking this trip that they felt the benefit derived from the trip was equal to at least three months' work in college. It is strongly urged that all members of the Junior Mechanical Engineering class should, if possible, arrange to take this trip during the spring vacation.

Digitized by Google

THE MICHIGAN TECHNIC

Old Engineering Bldg. **Ann Arbor, Mich.**

OFFICIAL ORGAN OF THE DEPARTMENT OF ENGINEERING OF THE UNIVERSITY OF MICHIGAN

Published quarterly in the months of October, December, March, and May by the Engineering Society

Vol. XXVII DECEMBER, 1914 Number 3

Publishing Staff

OLIVER W. HALL . . . . . Managing Editor
W. C. THOMPSON . . . . . Business Manager
DON A. SMITH . . . . . Managing Editor, Elect
L. C. ROWLEY . . . . . Business Manager, Elect

OLIVER W. HALL.

WM. C. THOMPSON.

Assistants

H. W. Rix
R. C. Glasier
T. D. Weaver
P. K. Hirth
M. S. Easton
C. E. Gormsen
F. E. Richardson
E. W. Higgins
C. M. Burns
M. L. Goldstein
J. H. Schmidt
H. E. Montelius
E. C. Smith
R. C. Eastman

Advisory Board

PROFESSOR EDWARD M. BRAGG . . . . . Chairman
ASSISTANT PROFESSOR A. O. LEE . . . . . Secretary
MR. H. R. LLOYD . . . . . Treasurer
ASSISTANT PROFESSOR J. R. NELSON . . . . Advisory Editor
ALLAN T. RICKETTS . . . . President Engineering Society

Digitized by Google

EDITORIAL

Our "Swan Song."

It is with regret that the present board takes up the publication of this issue of the Michigan Technic, as it means that, with this one, the control will pass out of their hands into those of the new board. It is, nevertheless, not given up without a certain feeling of satisfaction, as many things have been accomplished during the régimé of the present board. When the control of the Technic was turned over to it, things were in a bad way, and, at the suggestion of the board, the Engineering Society appointed a committee to investigate and report on the best plan for putting the Michigan Technic on the basis which it deserves. Through this investigation, which is discussed at length on another page of this issue, the Technic came to its own, and has enjoyed a more active existence than at any time in the previous four or five years.

For the first time in that period, the paper has been put on a satisfactory financial basis; not what it could be, but better than it has been in the past.

With the proper continuation of the policy established by the present board, through the cooperation of the Engineering Society, and earnest endeavor on the part of the members of the new board, the Michigan Technic can be put on a firm basis, where it may properly uphold the honor and dignity of the University which it represents. This cannot be done in a year, or two years, but is the ultimate goal which is to be attained. It will never be attained by letting the interest now aroused die out, but only will it be attained by the earnest efforts of each succeeding board to improve on the work of the last one. All success to the new Board!

New Technic Offices.

We announce with pleasure that we have removed our offices from the Old Engineering Building, where the Technic has been for many years, into the Engineering Society Rooms, in the New Engineering Building. The new offices are far more convenient and better arranged, and an improvement in the work of the staff has already been noticed.

Elective Courses.

It is common to hear, on all sides, the expression of the student to the effect that he has worked hard for three years, and has only 17 hours to get off to graduate, and he is going to slack off and take it easy for a year. Such a proceeding seems to be a veritable anti-climax to the culmination of the student's college course. At the very time when he is best prepared to study advanced courses with excellent professors, leaders in their respective lines; when he has all of his fundamentals thoroughly in mind; when he has no worldly cares to prey on him; and, most important of all, when he has time and opportunity to study these advanced courses, he sluffs on the job and lets opportunity knock unnoticed. Such actions on the part of the student show a lack of the determination to win; the determination which is so essential to success in the unfeeling world. Such actions show a tendency toward laziness and slothfulness, either of which will effectually ruin a man in short time.

The senior year is the year of college years. It is at that time that the

Digitized by Google

young engineer is preparing to enter in on his life work. His success in that life will depend, to a great extent, on his training in college. The more he knows about a certain subject, or several subjects, the better will be his chances for that success for which we all hope. His Senior year is the time to get those courses. Realize that it is the knock of Opportunity, and do not let it go unanswered.

Keeping A File.

There comes a time, sooner or later, in the life of every Engineer, when he remembers having read a certain article at some previous time, but he cannot place it, or does know how to look it up. Or he has in mind certain valuable data on a problem on which he may be working, but has no trace of its whereabouts. At such times the Engineer has the greatest need of a file of some sort for keeping articles, data, photographs, charts, etc., anything that he may have future use for.

There is any number of systems of filing and indexing articles, and almost any of these may be followed out with advantage. It is essential to pick out a system which will expand without congestion, as a system, in confusion, is worse than useless. Where possible, it is desirable to keep files of the complete magazines, with indices on the articles desired. Where this is impossible or undesirable, the particular articles or sheets may be slit out with a knife, and filed in cases of some sort. This latter system has the advantage that any articles bearing on a certain subject may be removed and readily carried about on a project.

The time to begin a file is when a man begins to read articles with interest and wish that he had some way to keep track of them. A little time spent in the development of some system for keeping such articles is well spent, and will be appreciated more and more as the years roll by.

Engineering Opportunities.

With each succeeding report of the war, with its tale of destruction and slaughter, comes the need of Engineers will be called on to assist in the of Europe. When the war comes to an end, as it is hoped it will in the near future, the greatest part of the rebuilding of the once ultra-civilized nations will be played by Engineers. Many of the greatest foreign Engineers are being sacrificed in the carnage of battle, and American Engineers to rebuild the shattered empires work of reconstruction.

Automobile Manufacture has been cut to practically nothing in Europe; many of the finest French and German factories have been destroyed, and many more will be destroyed before the termination of the war. This means that American manufacturers will have to design and manufacture cars for the world until Europe can get on her feet again.

All other branches of Engineering will have their parts to play in this work of rebuilding, and as a consequence, a vast field is to be soon opened to the Engineering graduates of the next ten years or more.

Engineeresses.

A new refining element has been gradually creeping into the Engineering Department within the last few years. Reference is made to the ever increasing number of young ladies who are taking up the study of Engineering. A few years ago it was not unusual to have two young ladies in the engineering classes, but last

Digitized by Google

year there were six and this year thirteen!

The young ladies have been making good, too, as examination of the roll of class officers of the Sophomore and Freshman classes will show. One of them is Vice-President of the Sophomore class, and another is Secretary of the Freshman class. They are upholding their end of the scholarship standards, also, and are not proving a drag on the classes in any way, as many have imagined. Two of the young ladies have set a good example for the rest in joining the Engineering society, and have thus signified their intention of helping out the Engineering Department in its inside work.

The girl who is not afraid of the hard, uneasing toil of the Engineer, who is willing to soil her dainty hands in the attainment of an engineering education, who is anxious to take such an active part in the upbuilding of the material world, deserves nothing but the highest respect and consideration of the Men in the Engineering Department.

Here's to the Girl Engineer!

Digitized by Google

DEPARTMENTAL NOTES

MICHIGAN ENGINEERING SOCIETY.

The annual meeting of the Michigan Engineering Society is to be held in Ann Arbor on January 19th, 20th, and 21st. The official headquarters during the convention will be the rooms of the Engineering Society, located in the New Engineerng Building.

The Michigan Engineering Society is an organization which deserves especial mention, on account of the affiliations which it has had with the faculty members of this University. It was founded in the early days before the present National Engineering Societies had grown to their present size, and for that reason, contains in its list of members, some of the most prominent engineers in this country. Dean M. E. Cooley was one of the founders, and is also a past President of the organization. Among the other past presidents are also: Professors J. R. Allen, J. B. Davis, H. E. Riggs, and Chas. E. Greene. The present President is J. J. Cox, of the Highway Engineering Department of the University. Mr. S. J. Hoexter, of the Mechanical Enginering facuty, is Secretary. The society was originally composed of surveyors and county engineers, but now includes in its membership the most prominent engineers of all classes.

Through Mr. S. J Hoexter, the Michigan Engineering Society extends an invitation to all members of the Engineering Society to attend its meetings, at which many interesting papers will be presented. There will be a banquet at the Union during the stay of the visitors, 200 of whom are now expected to come. The co-operation of all members of the Engineering Society of the University is requested in making the stay of the visitors as pleasant as possible.

RESEARCH.

Further Investigations by Prof. Zowski.

In his work to improve the water turbines for low heads, aiming to raise both the speed power values and the efficiency, Prof. Zowski has made further progress. This latest high speed, high capacity wheel exceeded the power of his last wheel, No. 5, by 25%, maintaining the same speed and raising the efficiency from 90.1% to 90.7%.

Wheel No. 5 had, under a 1 ft. head, a power of 3.31 with a speed of 50 R. P. M. and an efficiency of 90.1%—giving a "type characteristic" of 91. This new wheel develops under 1 ft. head a power of 4.17 with a speed of 50 R. P. M. and an efficiency of 90.7%—giving a "type characteristic" of 102.

It was generally believed by turbine theorists and designers that to attempt to design water wheels for "type characteristics" greater than 75 to 80, which means power values of 2.25 to 2.56 at a speed of 50 R. P. M. under 1 ft. head, would make the wheel entirely uncommercial. The work of Prof. Zowski disproves this theory.

Wheel Tests.

A series of tests has been conducted in the experimental laboratories of the University of Michigan by Asst. Prof. F. N. Menefee, to determine the Comparative Strengths of Steel, Wire and Wood wheels.

The wheels were tested in a Riehle machine with the support at the hub and the load applied at the rim. The load was applied in 500 lb. increments and the permanent deflection or set measured after each increment.

Following is a tabulated statement of deflections and loads:—

	DEFLECTION IN INCHES.		
Load Pounds on Rim	Steel Wheel.	Wire Wheel	Wood Wheel
500	0.001	0.001	0.013
1,000	0.041	0.030	0.033
1,500	0.055	0.120	0.075
2,000	0.068	0.215	0.121
3,000	0.099	0.425	0.210
4,000	0.110	0.533	0.312
5,000	0.143	.....	.....
6,000	0.233	.....	.....

Digitized by Google

The wood wheel failed at 4,500 pounds; two spokes in the wire wheel broke at 4,000 pounds, though no nipples pulled through the rim.

Hot Air Furnaces.

Assistant Professor J. E. Emswiler, in his course M. E. 22, Assisted by Wyeth Allen, M. N. Smalley and E. J. Kruszka, Senior Mechanicals, has been conducting a series of experiments on Round Oak hot air furnaces. Not much experimental work has ever been done on hot air furnaces, as the difficulties are so much greater than in the case of steam and hot water. The experiments are for the purpose of determining three things; 1st, the velocity of air as it goes thru a hot air furnace; 2nd, the coefficient of transmission of heat from the heating surfaces of furnaces; and 3rd, the efficiency of a hot air furnace.

Compressed Air.

Professor Emswiler is running a test to determine the coefficient of discharge of an orifice that can be placed in a pipe line carrying compressed air. The orifice is used with quite a low difference of pressure on the two sides. In this experiment, the Ingersoll-Rand Company, of Painted Post, N. Y., manufacturers of compressed air machinery, have sent a low pressure orifice box to facilitate measurements. E. J. Smith, H. S. Parsons and E. T. Thomas, are the senior mechanicals assisting.

The Disposal of Tannery Wastes.

Mr. Albert Roth, who was graduated from the department of Civil Engineering last June, spent the summer vacation as Assistant Engineer in the Engineering Division of the State Board of Health. During the greater part of the summer he was engaged upon a study of tannery wastes, particularly in relation to city water supplies and the pollution of streams, but with the opening of college he entered the University for a year of graduate study in Sanitary Engineering and is now continuing his investigation of the purification of industrial wastes important in Michigan, particularly those from tanneries.

In connection with this investigation he made a trip into western Pennsylvania in October, following which he read a paper in Chicago before the annual meeting of the American Association of Leather Chemists on the subject, "The Disposal of Sewage Wastes from Tanneries."

In this paper Mr. Roth showed that with the increasing demands for the protection of city water supplies from contamination and of all streams from injurious pollution, the tanning industry was being forced to meet a most serious and difficult problem. The liquid wastes from a tannery are large in volume and are extremely difficult to handle. So little is known regarding effective and economic means of disposing of wastes of this character that several tanneries, after making ineffectual attempts to reach a satisfactory solution of the problem of taking care of their waste products, have been forced to go out of business. A large amount of money has been spent on disposal plants, many of which are valueless and most are very far from being satisfactory. In his paper Mr. Roth was able to point clearly to certain fundamental principles upon which the economic design of purification plants for the disposal of tannery wastes must be based.

Marine Tank.

Prof. Sadler is at present investigating the question of ships' wakes by means of current meters. The meters are run with no model in front of them and then later with a model in front. The difference in revolutions gives the velocity of the water following the model.

A report on Experimental Towboats has been made by a board of Army Engineers and is contained in House Document No. 857, 63rd Congress, 2nd Session. The tests upon tow-boats and barge forms and upon radial and feathering paddle wheels were made in the experimental tank of the University under Prof. Sadler's direction.

Digitized by Google

FACULTY.

Appraisal Work.

The Pere Marquette Appraisal, which has been conducted by Dean Cooley with the assistance of Professor Riggs and Professor Anderson and many of the Engineering faculty and Alumni, is nearing completion. The preliminary report has been in several weeks and the final report will have reached the State Railroad Commission by the first of December.

The D. U. R. Appraisal of which Dean Cooley is also the head, is at this time over half finished. This Appraisal includes not only the Detroit City Lines but also all the Interurban lines owned by the D. U. R. in Michigan.

Designs Power Plant.

Professor John R. Allen is acting as Consulting Engineer for the Idaho Oregon Light and Power Company, installing a temporary installation at the Oxbow Bend Power House on the Snake River, Idaho.

The silent chain drive used is the largest in the world. Two waterwheels are hitched to each generator and 5,000 horsepower are developed.

New Faculty Members.

In the Engineering Mechanics Department, O. W. Boston has been raised to the position of instructor. Mr. Boston graduated in 1913.

The Surveying Department has taken A. N. Laird and C. N. Ward on the roll of Teaching Assistants. Both men are of the class of 1914.

Descriptive Geometry is now being taught by several men from other schools. They are: M. J. Orbeck. from the U. of Minnesota; F. A. Mickle, from Ohio State; and J. C. Palmer from the U. of Illinois.

Student assistants in the E. E. Dept. are G. B. Stuart, Grad. School; E. D. King, '15, and L. E. Delf, '15.

Sanitary System For Camp Davis.

A. N. Laird, Teaching Assistant in Surveying, is designing a sanitary system for Camp Davis. The plans include a septic tank and a sub-surface irrigation system.

MICHIGAN MEN IN THE PRESS.

Automobile Wheel Tests.

In the "Motor World" of April 9, 1914, appeared an article concerning the tests conducted by Asst. Prof. F. N. Menefee of the Engineering Department. The tests covered strengths of wooden and wire wheels under various conditions. Articles on the same subject apepared also in "The Automobile" of April 9, 1914, and in "The Scientific American."

Professor Menefee has lately been conducting a series of sewer-pipe tests for the Consolidated Coal Company of Saginaw. The object of the tests was to obtain a comparison of the strength of concrete pipe and double strength vitrified pipe.

NEW BOOKS BY MICHIGAN MEN.

Heat Engines.

J. R. Allen and J. A. Bursley.

Professor John R. Allen and Professor Joseph A. Bursley, of the Mechanical Engineering Department, realizing the advancement made in various types of heat engines during the past few years, have published a new edition of their treatise on Heat Engines.

The book is being handled by the McGraw-Hill Book Company and is meeting with wonderful success as a college textbook, being used in twenty some engineering schools.

Among the new subjects treated are the Stumf Uniflow Engine, the Humphrey Gas Pump and recent developments in boilers, stokers, steam turbines and gas engines. Many of the chapters have been rewritten and detailed explanation added which increase the value of the book as a text, and at the same time make it a valuable addition to any engineering library.

Digitized by Google

A New Book on Electrical Measurements.

A. W. Smith.

For the past ten years the subject of Electrical Measurements has been taught by Professor A. W. Smith, of the Department of Physics, during which time there has accumulated a system of notes covering the entire subject, and giving the best methods for class-room presentation. These notes have now appeared in the form of a book entitled "Principles of Electrical Measurements," which is being successfully used this semester.

Following out the author's practice of teaching simple things first, the book begins with a series of experiments in which the fundamental principles of the subject are emphasized and illustrated by the use of only the simplest apparatus in order to keep the attention of the experimentator on the principles involved rather than on the apparatus. Having established this foundation, the succeeding chapters take up in more detail the exact measurement of resistance, current, electromotive force, power, capacity, inductance magnetisation of iron, and the first notions of alternating currents, giving the complete theory in each case and explaining the best methods to be used. The calibration of electrical instruments forms an important section of the book, and the location of faults on a telephone line always convinces the class that electrical measurements are "practical." The treatment of the Magnetic Circuit is unique and fundamental, and gives to the student of electrical engineering a sane and logical basis for the further study of electrical machinery.

The publishers, McGraw-Hill Book Co., have produced an attractive volume, and their enterprize is shown by the fact that although the proof was read after the close of the Summer Session, the finished book was in the hands of the students the first day of this semester.

Low Head Water Wheels.

S. J. Zowski.

In the *Engineering Record* for November 28, there appeared an article by Professor Zowski in which he discussed the recent developments and improvements in the design of water wheels for low heads. As the article was written before the tests were made on his latest wheel, this wheel was not mentioned.

DEPARTMENTAL CLASSES.

Senior Class.

Early in the year the Senior Engineers elected the following class officers and managers:

President—O. W. Hall.
Vice-President—J. W. Raynsford.
Secretary—J. H. Bateman.
Treasurer—D. G. Ellis.
Football Manager—W. W. Candler.
Baseball Manager—W. H. Stewart.
Track Manager—J. H. Ferris.
Baseball Manager—A. R. Griffes.

Committees have been appointed to take charge of the various class duties and the full list of chairmen and committees will appear in the next issue.

The Social Committee, of which Frank Sheehy is chairman, has planned a dance, to be held in the near future. A Combination Senior Engineer-Senior Lit dance is receiving consideration.

The Union dinner committee, presided over by Art Griffes, held a very successful dinner at the Union, Tuesday, December 1. These are planned for every month and original features will mark each dinner.

The question of Senior Assembly is being discussed and a decision will probably be reached in the near future. Until this arrangement, speakers will be invited to all assemblies, giving the class an opportunity to hear some of the big men of the day.

Junior Engineers.

The Junior Engineers elected the following class officers:

President—Don Smith, Algonac.
Vice-President—Harry Buell, Saginaw.
Secretary—Howard Phillips, Ann Arbor.
Treasurer—Bob Hadley, Toledo, Ohio.
Basketball Mgr.—Walt. Reichle, Saginaw.
Track Manager—Jack Carritte, Detroit.
Baseball Manager—T. D. Weaver, Detroit.

Digitized by Google

A strong social committee was appointed and their ability was proven Friday evening, November 20, when the most successful smoker in the history of the class was held at the Union.

Francis Mack acted as toastmaster. Professor Allen, the faculty speaker, told of some of his early engineering experiences. Dad Ricketts talked about the Student Council, explaining its functions and its relation to the student body. President Smith gave an "Oration"; Clesson Bushnell, '15, sang a song; Scanlon, '16L, performed at the piano and sprung some original stuff, and Russell Mills led the Mandolin Raggers Quartet.

The first dance of the season, "The Mechanics' Ball," was held at the Union, December 4. It upheld the reputaion made by the "'16" Engineers in their Freshman and Sophomore years for giving the best class dances on the Campus.

The President and Social Committee of the class are working hard to get a J. Hop this year. A Junior Hop, under class management and minus the expensive and objectionable features of past years, is a campus institution that should be perpetuated.

Sophomore Class.

The following officers were elected by the class at a meeting held early in the year:

President—Geo. A. Scheibel.
Vice-President—Dorothy T. Hanchett.
Secretary—Thatcher W. Rea.
Treasurer—Louis F. Dieterich.
Football Mgr.—Edwin K. Marshall.
Baseball Mgr.—H. H. Whittingham.
Track Mgr.—H. L. Carroll.
Basketball Mgr.—Willis Brodhead.
Sergeant-at-Arms—E. N. Kendall.

No definite plans of the Sophomores could be obtained at time of going to press.

Freshman Class.

The following officers for the 1918 Engineer class were elected Wednesday, October twenty-first, in the Freshman Assembly:

President—Henry F. Dake.
Vice-President—E. I. Craig.
Secretary—Miss Dorothy Hall.
Treasurer—C. C. Smith.
Football Mgr.—Phil Raymond.
Track Mgr.—M. McKee.
Basketball Mgr.—F. R. Brown.
Baseball Mgr.—H. S. Knowlson

No definite plans for the year have been made.

Class Assemblies.

Last year at the request of the second and third year men the mentor and assembly system was extended to sophomores and juniors so that these classes might have monthly assemblies for class meetings and monthly reports on their studies through their mentors. The number in each group was so large, however, that the mentors were unable to give individual attention to their men and the number of men in a group has this year been reduced to twenty for sophomores and twenty-five for juniors. The mentors for these classes are assigned with reference to the branch of engineering which the student has elected in order that he may have an advisor in his special field. With this exception, however, the ideal relations between mentor and student are essentially the same, the mentor being in the words of the Dean "not merely an advisor about studies but an elder brother whose business it is to see that every man in his group gets the largest possible benefit out of his college life."

SOCIETIES.

The Engineering Society.

At recent meetings of the branches of the Engineering Society the following officers were elected:

Chemical Branch:—
President—J. T. Naylon.
Vice-President—J. R. Roberts.
Sec.-Treas.—C. C. Kennedy.

Civil Branch:—
President—A. T. Ricketts.
Secretary—H. G. Prussing.
Treasurer—R. F. Watt.

Digitized by Google

Student Branch A. I. E. E.:—
President—H. A. Enos.
Vice-President—E. D. King.
Secretary—H. W. Stubbs.
Treasurer—W. C. Weilbacher.
Student Branch A. S. M. E.:—
President—R. H. Mills.
Sec.-Treas.—C. H. McClellan.
Combined Societies:—
Sec.-Treas.—M. S. Reed.
Librarian—H. B. Bartholf.

All of the branches report active progress, and are getting plans under way for increasing membership in their branches. They have all held meetings, at which prominent men have spoken to the members, and during October, all united in a smoker in the Society rooms, where a pleasant evening was spent in getting acquainted and laying plans for the future.

Not in the past five years has the Society shown the active interest that it has this year, and it is believed that the new plan of reorganization is to be a success, in that it promotes the interests of the separate societies, both individually and collectively.

Sigma Xi.

The Society of Sigma Xi elected last June, ten undergraduates, eight of whom were engineers: Edmond W. Conover, Withred Cook, Gerhard Louis Luebblers, Floyd Lyddon Moon, Albert Roth, Chester Schoepfle, and Byron H. Stuch. The graduates chosen were: Herbert John Cutler, Carl Louis Schuman, James Wightman Follin, and Chester Owen Wister.

Tau Beta Pi.

The following men of the 1915 Engineering Class were chosen to membership in Tau Beta Pi, the National Engineering Honorary Fraternity. Membership in this Fraternity is based upon scholarship primarily, and then consideration is taken of the man's general all around characteristics in his classes and on the campus. All selections are made from the highest one-quarter of the class. The men selected were:

Wyeth Allen, Hood River, Oregon.
Harold E. Wheeler, Chicago, Ill.
Hershel C. Smith, Phoenix, Arizona.
Edward R. Young, Toledo, Ohio.
Hermann G. Mueller, Mt. Clemens, Mich.
Peter Tazelaar, Kalamazoo, Mich.
Clarke R. Greene, Salem, Ohio.
Ira H. Reindel, Detroit, Mich.
Norman S. Flook, Dunkirk, N. Y.
Ralph B. Dibble, Ann Arbor, Mich.
C. Hjalmer Flink, Ironwood, Mich.

The initiation was held on December 2nd, after which a banquet was served the new members and the faculty.

Phi Lambda Upsilon.

The following men were elected to membership in Phi Lambda Upsilon, the Honorary Chemical Society, and initiated this Fall:

H. A. Depew, E. H. Woodhouse, J. R. Dean, H. F. Wood, E. R. Young, P. L. Miller, N. A. Sanger and E. A. Rykenhoer.

Vulcans.

At the Fall election of Vulcans, the Senior Honorary Engineering Society, the following men were chosen to membership: H. C. Smith, T. H. Bushnell, J. C. Abbott, J. H. Ferris, G. D. Douglas, L. F. Terry, H. L. Bockstahler, D. G. Ellis, W. T. Smith, W. W. Candler, and W. W. Calkins.

The initiation and banquet were held on October 28th, 1914. At the banquet F. W. Sheehy acted as toastmaster, and the following men responded to toasts: Prof. H. C. Sadler, Prof. A. J. Decker, Prof. Gardner S. Williams, A. R. Griffes, and J. C. Abbott.

Triangles.

Triangles, Junior Honorary Engineering Society, initiated ten men on November 4th. They are: John Carritte, Norman James, and Wallace Reid of Detroit; Harry Buell of Saginaw; John Norton of Ontonagon; Walter Sterling of Negaunee; Thomas Trelfa of Alpena; Francis Mack of Toledo, Ohio; Macdonald Reed of Erie, Pa.; and Harold J. Smith of Wilmette, Ohio.

Digitized by Google

Professor A. E. White of the Chemical Engineering Department and Professor H. E. Riggs of the Civl Engineering Department spoke at their initiation banquet at the Michigan Union.

QUARTERDECK.

Nine Upper Class Marine Engineers were initiated into Quarterdeck November 20, 1914. Part of the ceremony consisted in parading the initiates about the campus—clad in sailor suits and bearing oars.

Those selected were: J. Silverman, '15E; A O. Adams, '15E; C. H. Sung, '15E; C. Williams, '15E; W. C. Cook, '16E; N. L. Goldstein, '16E; L. McCarthey, '16E; C. L. Mattison, '16E; J. S. Bibber, '16E.

"JIMMIE" RAYNSFORD, '15E
Captain of the 1914 Varsity Football Squad

ENGINEERS WIN MONOGRAMS.

Five engineers were among the sixteen men who won football M's this fall. Captain James Raynsford, '15E, of Detroit; Earnest Hughitt, '15E, of Escanaba; Leland H. Benton, '16E, of Valparaiso, Ind.; John J. Lyons, '16E, of Pittsburg; and Thomas H. Bushnell, '15E, of Cleveland, Ohio.

The awards are made on the basis of service to the team. Faithfulness in practice, and spirit on and off the field are all considered.

R's were awarded to thirty players, an unusually large number on account of the strenuous season. Eight were engineers: Floyd C. Morse, '15E; Edward J. DePree, '15E; E. W. Miller, '15E; John K. Norton, '16E; Robert F. Kohr, '17E; Clarence O. Skinner, '17E; James L. Whalen, '17E; and Samuel Cohen, '17E.

"TOMMY" HUGHITT, '15E
Quarterback and holder of the Heston-Schulz trophy for the most valuable man to the team.

Digitized by Google

"MAULEY" MAULBETSCH, '17P
All-American Halfback.

THE DEPARTMENT ENROLLMENT.

The enrollment in the Engineering Department this year has been particularly gratifying to the officers. On account of the war and the consequent scarcity of money in the United States, it was feared that many prospective students would be unable to enter and old students return.

According to Assistant Dean Butts, however, not many more than the usual number of those who had been admitted, have failed to appear at the opening of college. Of those who responded to a letter of enquiry, seventeen gave a lack of funds as the reason for their non-attendance. Nineteen had entered other universities, principally to be nearer home or for a slight saving in fees. Thirteen gave general reasons for their non-attendance and twelve gave no reason at all.

On the whole, then, the war has not made such a difference in attendance as it has perhaps affected the expenditures of those who did come.

The folowing table shows the comparative enrollment by departments:

NUMBER OF STUDENTS IN ENGINEERING DEPARTMENT, 1914-1915.

	FIRST YEAR	SECOND YEAR	THIRD YEAR	FOURTH YEAR	SPEC.	TOTALS NOV. 1914	TOTALS NOV. 1913
Civil Engineering		127	102	73	8	310	273
Mechanical Engineering		107	89	92	2	290	273
Electrical Engineering		81	60	37	6	184	170
Chemical Engineering		51	51	37	1	140	137
Marine Engineering		16	13	10	1	40	30
Architectural Engineering	25	12	17	8	}	37	29
Architecture I	14	8	6	2	} 6	16	14
Architecture II	10	18	11	7	}	36	22
Freshmen Eng.	384					384	399
B. S. E.							4
Totals	433	420	349	266	24	1492	1404

FIGURES SHOW BIG INCREASE OF UNIVERSITY ENROLLMENT.

Following are the figures for Nov 1, 1914, as compared with those of Nov. 1, 1913:

Digitized by Google

Department	1914	1913
Literary	2582	2520
Dental	318	282
Graduate	258	225
Law	499	553
Medical	304	278
Homœopathic	74	75
Pharmic	110	96
Engineering	1247	1282
Architecture	145	120
Total	5637	5431
Registered twice	115	127
Net	5522	5304
Summer Session	1594	1402
Total	7116	6706
Registered twice	797	698
Grand Total	6319	6008

ELECTRICAL ENGINEERING.

The following changes in the Electrical Engineering Course have been ratified by the faculty:

1st. E. E. 2 is put in the first semester of the junior year in place of electives, putting E. E. 3 and E. E. 4 one semester ahead of their previous locations.

2nd. E. E. 12 (transmission course) is increased from 2 to 3 hours.

3rd. Hydromechanics (2 hours) is hereafter required of electrical engineering students, to precede E. E. 11 (generating stations).

The increasing popularity of the electrical engineering course at Michigan is shown by the statistics of Sophomores electing E. E. in the last three years:

1912-1913	49
1913-1914	59
1914-1915	81

The following new apparatus has been installed in the E. E. Laboratory:

One 2.5 K. W. Dynamotor, changing 110 volts continuous current to 25 volts continuous current.

One 5.0 H. P. 3-phase 220 volt wound-rotor induction motor, with starter.

Ten new meters, including ammeters, voltmeters, wattmeters.

Two series transformers.

One new type Magnetite arc lamp with prismatic diffused and high efficiency electrodes.

One 10 H. P. Fairbanks-Morse wound-rotor induction motor, with automatic resistance-starter.

MECHANICAL ENGINEERING.

Mr. S. R. Thomas, Teaching Assistant in the Mechanical Engineering Department, was married to Miss Claribelle Armitage, '11, of Highland Park, Mich., on August 21, 1914.

As a member of the Society of Automobile Engineers Asst. Professor Fishleigh has received a request for tests on proper tap drill sizes and for experimental work leading to the development of a formula for destructive effect of vehicles on roads.

Asst. Professor W. T. Fishleigh of the Mechanical Engineering Department acted as expert last summer in the patent infringement suit brought by W. S. Austin against the Cadillac Motor Car Co. of Detroit. The case was tried in the United States District Court in Grand Rapids but as yet no decision has been rendered.

ARCHITECTURAL DEPARTMENT.

The S. S. Kresge Company has just presented to the Department of Architecture a beautiful plaster model of the new Kresge building. This building is 18 stories in height and stands on Adams Avenue West, Detroit. The model is about four feet high and is made at a scale of one-quarter inch to the foot. It is an exquisite piece of workmanship by Siebert & Company of Detroit. The architect is Albert Kahn and Ernest Wilby, Associate of Detroit. The model is valued at about $500. From a teaching point of view this model will be most helpful since it illustrates thorough going modern design in an office building of to-day. The design is very simple and direct; there is a large amount

Digitized by Google

of glass in proportion to the structural frame. The steel frame is clothed with dull-glazed white terra cotta which is well simulated by the white plaster of the model. In this design the conventional cornice, which has little or no significance on a building of this type, has been omitted and is replaced by flat decorative bands which are in harmony with the rest of the design and in keeping with the character of the material. The long vertical lines in the facade clearly mark the structural frame work. The skillful handling of the design makes it possible to introduce large plate glass windows in the lower two stories of the building without giving the upper part of the design the appearance of over loading the lower portion.

It is proposed to color certain minor portions of the building so as to further approximate the actual effect of the building as it now stands in Detroit.

The generous gift of the Kresge Company constitutes the most important thus far received by the Department of Architecture. It forms a most important addition to the equipment of the Department and will, it is hoped, soon have several companion models.

DEPARTMENT ENTERS EXHIBITION OF WORK.

Michigan has been selected as one of ten institutions giving architectural courses, to make an exhibition of work done in the department, at the annual convention of the American Institute of Architects, to be held in Washington, D. C., on December 2, 3, and 4.

The following universities and technical institutes will be represented: Columbia, Cornell, Harvard, Pennsylvania, California, Illinois, Washington University, of St. Louis. Massachusetts Institute of Technology and Carnegie Institute of Technology.

Each exhibitor will be assigned a space of eight feet by ten feet, and the department of architecture has prepared three large stretchers, with which to fill its space.

? NEW SURVEYING BUILDING?

There is a rumor to the effect that a new Building for the Surveying Department is under consideration. It will be a welcome addition, indeed, to the group of splendid buildings now on the Michigan Campus. The old building has about seen its period of usefulness, and is, in fact far overcrowded at the present time.

UNIVERSITY EXTENSION SERVICE.

In the university extension service for 1914-1915, the number of professors from the Engineering Department shows the increasing interest thruout the state in engineering subjects. The following professors in the Engineering Department are on the list of speakers for 1914-1915:

John R. Allen, H. C. Anderson, Benjamin F. Bailey, L. H. Boynton, Edward M. Bragg, E. D. Campbell, Dean M. E. Cooley, J. J. Cox, W. T. Fishleigh, H. H. Higbie, Wm. C. Hoad, C. T. Johnston, S. F. Kimball, Emil Lorch, E. B. Merrick, G. W. Patterson, Beverley Robinson, H. C. Sadler, E. E. Ware, A. E. White, A. H. White, S. J. Zowski

Many of the subjects announced should prove of very general interest. One of Prof. Boynton's subjects is, "Florence as Seen by an Architect," illustrated with Lantern slides. Dean Cooley will speak on, "The Relation of Public Utilities to the Public." Mr. Cox has several lectures. one of which should be of very especial interest to the people of Michigan, "Michgan's Dollars and Michigan's Roads." Prof. Robinson has three very interesting illustrated subjects: "The Gothic Cathedrals of Europe;" "Among the Cathedrals of England;" "The Royal Palaces and Chateaux of France." Prof. A. H. White speaks on a subject that is daily becoming more vitally important, namely, "The Chemist versus the High Cost of Living."

The value of the extension service has been increasing year by year as evidenced by the increased number of lectures in 1913-1914 and by the increased average attendance. Prof. Henderson, who is at

Digitized by Google

the head of the Extension Bureau, expects this year to be the most successful in the history of the work.

POWER PLANT PROGRESS.

The New Power Plant will be doing all the campus heating and lighting after December 1st, and the old plant will be out of commission, except for the switch board. It is planned to make the old plant a part of the mechanical laboratory of the University, greatly increasing the facilities for research, and relieving present congestion. The hospital plant will be kept in operation for the present.

The switch-board recently installed in the New Power plant is one of the few in the country built of glass and is, therefore, of special interest. All switching is controlled from this panel except the oil switches, which are operated by a system of levers.

All steam-fitting, plumbing and electric wiring in the New Science Building is being installed by the University Buildings and Grounds Department of which J. H. Marks, '08M, is Superintendent.

MUSICAL ENGINEERS.

That the Engineering students are not so prosaic and narrow minded as to never let their eyes pass beyond the end of their slide rules, is shown by the number in the roll of the "Michigan Band." This is the 'Varsity band that astounded Harvard when it marched on Soldier's field last November at the time of the Michigan-Harvard game, and covered itself with glory.

Among the Engineering students who are taking part in the band are: L. O. Arnold, '15; E. M. Brady, '15; A. B. Castle, '16; M. B. Cutting, '17; H. B. Forsythe, '17; F. C. Wheeler, '15; C. B. Worth, '15. Mr. Hoexter, of the Mechanical Engineering Faculty, is the Manager of the band, and under his management, the organization has had by far the most successful year in its existence.

Digitized by Google

ALUMNI NOTES

R. A. Plumb, '06E., had a narrow escape from being caught in the European war. He expected to be in Berlin on August 15 to appear in some litigation over a German patent of his but saw when he reached London that it was useless to proceed. Mr. Plumb has for eight years been associated with the Trussed Concrete Steel Company of Detroit and is now general director of a separate company organized as the Trus-Con Laboratories, which handles and manufactures protective coatings for concrete. Mr. Plumb has become a specialist on protective coatings and has valuable patents of his own. He has recently started a new monthly magazine entitled "Structural Conservation" to further the science of water-proofing.

B. M. Ferguson, holder of the Gas Fellowship for the year 1909-10 has recently been appointed supervisor of the Gas Bureau of the City of Chicago. Mr. Ferguson, after leaving the university, was with the engineering department of the Detroit City Gas Company and with the Lloyd Construction Company. It is pleasant to know that he obtained his present position solely on the ground of his training and experience and without any political influence. His first report bears the date of October 1, 1914, and contains, in addition to the statistics concerning the work in the City of Chicago, considerable information concerning the history of the People's Gas, Light and Coke Company and the various reorganizations it has undergone. A statement in one of the gas journals intimates that this was issued as a preliminary to a campaign for fifty cent gas in the City of Chicago.

1897

Stephen C. Babcock and Elmer W. Hagmaier, '10e, have formed a partnership as Chemists and Chemical Engineers with laboratories at 803-805 Ridge Road, Lackawana, New York.

1899

James R. Bibbins of Chicago has been engaged by the Law Department of the City of Pittsburgh in an advisory capacity in connection with the present proceedings for the improvement of local transportation conditions in that city.

1902

Frederick C. Wilson has been for over a year superintendent of the Mayari division of the Spanish Iron Co. Address, Felton, Cuba.

1903

Frank I. Louckes became in July, 1913, U. S. Asst. Engineer in charge of the operating and care of the Louisville and Portland Canal and Dam No. 41, Ohio River. Address, Locks of L. & P., Louisville.

Robert B. Otis is Professor of Engineering at the Central Continuation School, Milwaukee, Wis.

Stuart K. Knox is with Nicholas S. Hill Jr., consulting engineer, 100 William St., New York City.

1904

Charles A. Waring has severed his connection with the electrical engineering department of the National Cash Register Co., and is now with the Engineering department of the Reo Motor Co. of Lansing, Mich. His address is 1000 S. Washington St., Lansing, Mich.

1905

Daniel A. White, who has been in Sonora, Mexico, for some years has returned to Los Angeles, where he may be addressed at 2941 S. Vermont Ave.

1907

Robert M. Hidey who has for several years been connected with the testing and designing department of the Packard Motor Car Co., took a flying trip through the East this summer in one of their test cars.

1908

Born to Ralph John Reed and wife, a son, John Miller, on May 28, 1914. Address, 1552 Third Ave., Los Angeles, Cal.

Digitized by Google

J. Mitchell Watson has removed from Wilkesbarre, Pa., to Detroit, where he is associated with the Oxygen Decarbonizer Co., 658 Fort St. West. Mr. Watson's residence address is 3077 W. Grand Boulevard.

Thomas R. Wooley is now with the Eastern Bridge and Structural Co., at their Worcester office. Mr. Wooley has lately been married and is living at the Hotel Bellmar.

Henry B. White, "Cy," was forced to leave Paris on account of the war. He has been in the U. S. about a month.

1909

Born to Mr. John T. Walther and wife, a daughter, Ruth Emeline, on June 4, 1914.

Robert H. Foreman is employed as a checker with the Lewis Iron Works, Detroit, Mich. His address is 503 Hurlbut Ave.

1910

First Lieutenant Gladeon M. Barnes of the Ordinance Dept. of the U. S. Army, has been transferred from the Watertown Arsenal to Frankfort Arsenal, Philadelphia, Pa.

1911

Herman C. Kiefer of Canton, Ohio, is now connected with the Timken-Detroit Axle Co. His address is 252 E. Grand Boulevard.

Lieut. Gustavus R. O'Connor of the U. S. Revenue Cutter Service is now stationed at Honolulu on the U. S. S. Thetis.

Wilson H. Richards, U. S. Surveyor, has been transferred from Clifton, Va., to Alzada, Mont.

Dulcidio de Sanza Pereira is employed by the Sao Paulo Tramway, Light and Power Co., Ltd., of Sao Paulo, Brazil. His address is Caixa 219, Sao Paulo, Brazil.

1912

Aubrey E. Burnham is now employed in the Engineering Department of the Cleveland Construction Co., East Waco, Texas.

Ralph J. Gaudy is chief construction engineer of the Detroit Edison Co.'s Indian Village plant.

Raymond G. Urch, who has been teaching at the Nobeck Middle School, Miyazaki Ken, Japan, left last Spring for a globe trotting tour. He expects to reach the United States in about a year.

Richard H. Wilson has been transferred from Willits, Cal. to Garberville, Cal., where he is serving as assistant resident engineer attached to Division No. 1 of the California Highway Commission.

Dale I. Parshall is Superintendent of the Machine Dept. of the Singer Mfg. Co., of South Bend, Ind. His address is 44 Rushton Apt.

William C. Randall is in the Engineering Dept. of the Detroit Steel Products Co. His address is 1870 Woodward Ave., Detroit, Mich.

Otto E. Boertmann is assistant to the Supt. of Construction of the France Stone Co., Toledo, Ohio. Address, 2319 Vermont Ave.

Franz W. Fischer is with the Liquid Carbonic Acid Co., 3100 S. Kedizie Ave., Chicago, Ill.

Harold L. Frackleton is with the Edison Illuminating Co. of Detroit, Mich. His address is, 185 Charlotte Ave.

Daniel W. Hayes is Superintendent of the Edison Co. in Ann Arbor.

Frank B. Lounsberry is a mettallurgical engineer with the Holcomb Steel Co., at Syracuse, New York.

George W. Armstrong has recently been called to the University of Wisconsin as instructor in metallurgy. After graduation from the university he was with the Midvale Steel Company of Philadelphia for a year as metallurgist and from there went to the Engineering Station of Iowa State College as a research worker. It was from this place that he was called to the University of Wisconsin.

S. S. Lawrence has recently sent to the university a package of oil-bearing pine nuts from Manchuria. The high price of linseed oil has caused diligent search for a substitute and many oils from Asiatic sources are being investigated. Mr. Lawrence was formerly with the Pennsylvania Steel Company in San Francisco, but is now connected with the import department of the W. R. Grace Company, a firm which imports materials largely from South America and Asia.

Digitized by Google

1913

Roland H. Stock of the U. S. Reclamation Service, has been transferred from Ronan, Mont. to Polson, Mont.

Otto F. Stuefer is in the commercial engineering section of the National Lamp Works, of Cleveland, Ohio. He is in charge of the development of new fields for miniature lamps.

Merl N. Taber is assistant chemist for the National Supply Co., Wagon Works, Toledo, O. His home address is 2040 Glenwood Ave., Toledo.

George A. Taylor is with the Tungstolin Works of the General Electric Co., Cleveland, O. Address, 1900 Euclid Bldg.

Michael Terry is a designer of special and automatic machinery, tools, fixtures and safety devices for the Champion Ignition Co., Flint, Mich.

Harold H. Todt is in the testing department of the Maxwell Motor Co. Inc., Detroit, Mich. Home address, 550 14th Ave.

Stephen R. Truesdel, is in the valuation department of the Chicago and Northwestern Ry., 226 W. Jackson Blvd., Chicago, Ill.

Earl W. Tucker is a chemical engineer with the Penn Salt Mfg. Co., Wyandotte, Mich.

W. Howard Turpin is in the traffic department of the Chicago Telephone Co., 230 W. Washington St., room 34, Chicago, Ill. His home address is 1725 Wilson Ave.

Born, to W. Arthur Grove, and Mrs. Grove, a son, Woodward Arthur, on July 18, 1914. Address, 230 S. Greenmount Ave., Springfield, Ohio. Mr. Grove is employed in the hydraulic engineering department of James Leffel & Co., of Springfield.

Helen Hamilton is a civil engineer with Professor H. E. Riggs, Ann Arbor. Her address is 714 Lawrence St.

Born, to Edward T. Lazear and Grace Fairman Lazear, '12, at Chefoo, Shantung, China, a daughter, Emily Elizabeth, on July 28, 1914.

John L. McCloud is assistant foreman with the Morgan & Wright Rubber Co., of Detroit, Mich. His residence address is 900 Third Ave.

William M. Mills, formerly in the U. S. Engineer Office, Rock Island, Ill., is now employed by the Dubuque Boat and Boiler Works, Dubuque, Ia.

Frank L. Weaver, who taught last year in the University of Oklahoma, is a draftsman with G. S. Williams, Ann Arbor.

Joseph T. Reader is estimating for James W. Partlan, Heating and Ventilating Contractor, 51-53 Park Pl., Detroit, Mich. His home address is 484 Ferdinand Ave.

John W. Richardson is a draftsman with the Baird Machine Co., of Bridgeport, Conn. His home address is 32 Waterville St., Waterbury, Conn.

Arthur C. Rissberger is in the engineering department of the Rochester R. R. & Light Co., 34 Clinton Ave. N., Rochester, N. Y.

Joe E. Rosatti is an architectural draftsman with Cowles & Mutscheller, Architects, 1-6 Chase Blk., Saginaw, Mich.

Henry A. Rothchild is a chemist with the Kimberly Clark Paper Co., Kimberly, Wis.

Carl W. Sanzi is a mechanical draftsman with Gardner S. Williams, Consulting Engineer, Ann Arbor.

Saul Saulson is a mechanical engineer with Albert Kahn, Architect, 58-60 Lafayette Blvd., Detroit, Mich. Home address, 75 Palmer Ave. E.

William T. Schepeler, formerly with the Carborandum Company, of Niagara Falls, N. Y., is now connected with the Union Carbide Company, of Niagar Falls.

Raymond G. Schaefer is employed as a draftsman with the Bower Rolling Bearing Co., Detroit, Mich. His residence address is 55 Atkinson Ave.

F. Tolbert Schreiner is a salesman for the Spencer Heater Co., 816 Ford Bldg., Detroit, Mich.

Walter T. Schuett is with the Canadian Bridge Co., Walkerville, Ont., Canada.

John H. Schumann is with the Edison Illuminating Co., of Detroit, Mich. He has been working on the electrical layout of their new steam power plant.

Roy L. Sessions is a chemical engineer with the Vanadium Alloys Steel Co., Latrobe, Pa.

Digitized by Google

Norman K. Sheppard is in the engineering department of the Saginaw-Bay City Ry., Light & Power Co. Address, 1220 S. Jefferson St., Saginaw, Mich.

Fred R. Sheridan is a draftsman in the office of the Superintendent of Public Works, Highland Park, Mich. Residence address, 767 Cass Ave., Detroit, Mich.

Allen F. Sherzer has been in the engineering department of the Union Carbide Co., Sault Ste. Marie, Mich., since graduation. Address, 318 E. Spruce St.

Clarence G. Smith has removed from Bay City, Mich., to Midland, Mich., where he may be addressed at Boz 530.

Clifford L. Snyder is with the Algoma Steel Corporation Ltd., Coke Oven, Sault Ste. Marie, Ont. For five months and a half after graduation he was results man, doing research work and plant testing, including the care of all recording instruments on the coke plant. In January he was promoted to the position of oven foreman. Address, "The Bungalow," Sault Ste. Marie, Ont.

Frederick W. Spangler has been mechanical draftsman with the Liquid Carbonic Co., of Chicago, Ill., since November. Address, 3100 Kedzie Ave.

Valentine F. Spring is a hydraulic engineer with the Fargo Engineering Co., of Jackson, Mich.

Lyman R. Flook is chief draftsman in the superintendent's office of the Buildings and Grounds Department of the University. Address, 616 Church St., Ann Arbor.

Walter F. W. Freund is in charge of the power efficiency work, with the Morgan and Wright Co., Detroit, Mich. Address, 245 Seventeenth St.

Jaswant R. Gandhi is in the drawing department of the American Blower Co., Detroit, Mich. Address, 35 Jefferson Court.

Frank C. Gibbs is representative for the National Regulator Co., of Chicago, with offices at 464 Spitzer Bldg., Toledo, O.

William C. Giffels is with the Fargo Engineering Co., Jackson, Mich. Address, 120 Fourth St.

John H. Gillooly is draftsman with the Marion Steam Shovel Co. Address, 326 W. Church St., Marion, O.

George L. Glasgow has been since February engineer with the Canton Eng. & Elec. Co., of Canton, O. From June to February he was assistant and electrical engineer with the Goodyear Tire & Rubber Co., of Akron, O.

Earle P. Gray entered the employ of the Grand Trunk Railway in Detroit, Mich., as instrument man on grade separation. Address, 218 McGraw Ave.

Ebenezer O. Grosvenor is with the Morgan and Wright Plant of the U. S. Rubber Co., Detroit, Mich. His home address is 1429 Grand River Ave.

Roscoe C. Hain is with the traffic department of the Central Union Telephone Co., of Chicago, Ill.

Emory R. Hartsig has been since January with the firm of Jewett, Bigelow & Brooks, 1109 Penobscot Bldg., Detroit, Mich., as a fuel engineer.

Herbert S. Hewitt has been employed in the War Department of the U. S. Civil Service at Rock Island, Ill., as a naval architect and steel hull inspector, since graduation.

Kirke K. Hoagg has held since graduation the office of assistant engineer with the Hyatt Roller Bearing Co., of Detroit, Mich. His home address is 119 Chandler Ave.

Ira T. Hook is physical testing engineer for the General Motors Co., of Detroit, Mich. Address, 88 E. Congress St.

Walter S. Hopkin is a draftsman with the Liquid Carbonic Co., 31st St., & Kedzie Ave., Chicago, Ill. His home address is 3210 Arthington St.

Louis H. Hosbein, Jr. is assistant efficiency engineer with the Public Service Co., of Northern Illinois at Oak Park, Ill.

Herbert A. Hosner has been employed in the testing department of the General Electric Co., of Schenectady, N. Y., since last July. Address, 927 Campbell Ave.

Walter J. Howard taught mathematics in the high school of Newport News, Va., this year.

Percy J. Hubbard is with Morgan & Wright, Detroit, Mich. His home address is 46 Perry St.

Digitized by Google

An engineer without a fair knowledge of Photography, like a tail-less dog, is incomplete. Learn how now, while in school, it may be of value to you at any time.

I can furnish you

Absolutely Anything Photographic

At the Lowest Prices

LYNDON **719 N. Univ. Ave.**

LUFKIN

Measuring Tapes and Rules

could not have lead the field in spite of all competition for a quarter of a century without possessing sterling quality. They could not lead the field today if they were not recognized as THE BEST—ABSOLUTELY. When you buy follow the SOUND JUDGMENT OF EXPERIENCE.

CATALOG ON REQUEST

Saginaw, Mich. THE LUFKIN RULE CO. *New York*

THE ANN ARBOR PRESS

OFFICIAL PRINTERS TO

The University of Michigan

And Its Student Publications

We print anything, from your name on a card to a book

Printers of this magazine

Press Building

Telephone No. 1 Ann Arbor, Michigan

Digitized by Google

Harold W. Hunt has been employed as an apprentice by the Detroit City Gas Co., since July 15, 1913. His home address is 645 Baker St., Detroit, Mich.

Eric F. Hyde is employed by the Edison Illuminating Co., of Detroit, Mich., as a mechanical engineer in experimental work.

Clifford P. Jaedecke has been with the Chicago Telephone Co. since graduation. His home address is 444 E. 46th Place, Chicago, Ill.

Ram Kishan Khosla is consulting and advertising engineer for the Fairbanks Morse Co. in Calcutta, India. His home address is Garhshan Kar Dist Hoshiar-Pur, Punjab, India.

John J. Krauss is assistant city engineer in Ann Arobr. Address, 200 N. State St.

Irving E. Lattimer has been with the Chicago Telephone Co., in their engineering department, since September. Address, 230 W. Washington St., Chicago, Ill.

Raymond E. Lauer is a chemist with the Maxwell Motor Co., of Detroit, Mich. His home address is Monroe, Mich.

Maurice A. Lebensburger is secretary-treasurer of the General Engineering Co., 325 Electric Bldg., Cleveland, Ohio.

Frank G. Legg has been since January, assistant state sanitary engineer, with offices at 312 Prudden Bldg., Lansing, Mich.

1914

Edward T. Anderson may be addressed at 55 Kisam Hall, Nashville, Tenn.

Carl E. Guthe is enrolled in the graduate school of Harvard, and is working towards his Ph.D degree. He is specializing in archaeology.

Edwin C. Hasse is in the U. S. Reclamation Service at Fletcher, Mont.

Lester J. N. Keliher is engaged in promoting work for the Universal Portland Cement Co., Chicago, Ill.

Harold J. LaLonde is working for the Bituminous Products Co., Detroit, Mich. Residence, 32 Watson St.

A. O. Williams is employed in experimental work for the Hyatt Roller Bearing Co., Detroit, Mich.

Digitized by Google

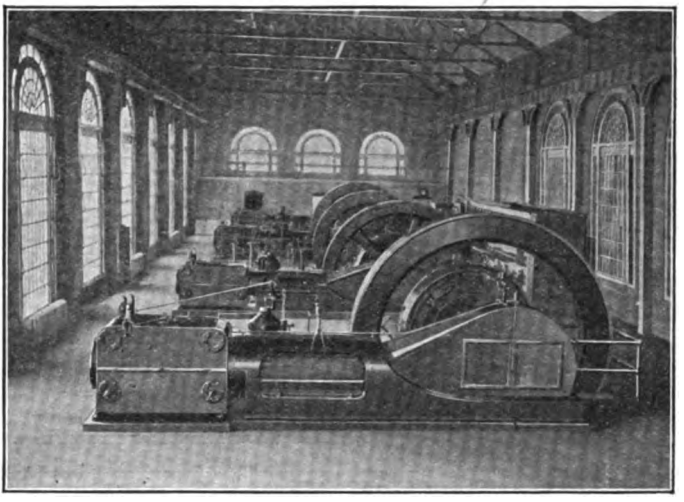
FIVE MILLION HORSE POWER

in Corliss Engines and

Four Hundred Thousand Horse Power

in Gas Engines—built by

Allis-Chalmers Mfg. Co.



ALLIS-CHALMERS CORLISS ENGINES

ALSO BUILDERS OF

Blowing Engines	Air Compressers
Oil Engines	Condensers
Steam Turbines	Hydraulic Turbines
Generators	Motors
Mining Mchy.	Flour Mill Mchy.
Pumping Engines	Saw Mill Mchy.
Centrifugal Pumps	Forgings

MAIN OFFICE AND WORKS

MILWAUKEE, WIS.

Digitized by Google

EDITED BY HAROLD SCHRADSKI.

UMP!

The engineer's a busy cuss
He hasn't got the time to fuss
And in his transitory way
He sees how much he can survey.

* * *

Dean—Hm--you've been up before me before.

A. E.—That so? What time do you get up?

* * *

C. E. NOTES.

M. E.—Rodman ha scopped off the choice job of Piledriver-in-Chief for the Building and Shack Construction Co.

T. R.—Ansit, '85, has offered a noble prize to the 1915 E who writes the prettiest essay on "Lilies of the Valley."

* * *

The cleverest feature of the fancy dress ball at Whitmore Lake last week was the Engineer Quadrille and the Axe and Plumb Bob Carrying Contest.

(Apol. to Princeton Tiger).

* * *

GRAPHICALLY SPEAKING.

'17—Did you hear about how the Architects' exam came out?

'18—No, how did it end?

'17—In a draw.

EVEN ENGINEERS HAVE SOULS.

This of course has the appearance
Of being a regular poem, but it is
Actually the kind of stuff a C. E.
Likes after studying "Materials of
Construction" and "Prime Movers."

* * *

C. E. TERMS.

In Paris—French Curves.
Down Town—Bottom sway bracers.
Boarding House—Drop plate.
League Fussing—Retaining walls.
At the Dean's Office—Suspension lines.

* * *

THRILLING FACTS FOR THE CHEMICAL ENGINEER.

Minaniata, Japan, produces 40,000 tons of calcium cyanamide annually.

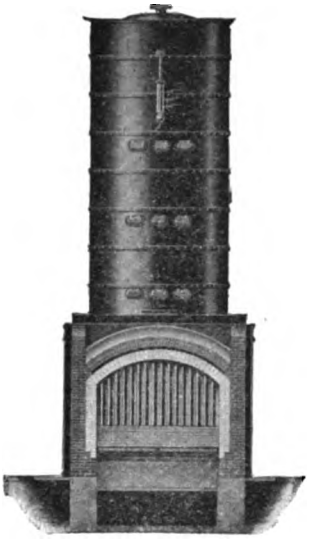
In the desert regions, modern chemists have found water immensely valuable for irrigation purposes.

Wood as a fuel is not of great industrial importance though its domestic use is very extensive.

Umpfschnitt, of Dublin, has discovered that hydraulic gypsum, completely dehydrated, with grains of anhydride fully developed, and whose basic calsium sulphate increases with rising temperature, is very nice.

Digitized by Google

The Wickes Vertical Water-Tube Boiler



Very high thermal efficiency is obtained from this boiler and setting, because:—

1st—High furnace temperature results from Dutch oven.

2nd—Gases entirely surround and closely scrub heating surface from entrance to release.

3rd—The gases cannot leave the heating surface. There is no possible chance for short-circuiting.

4th—Boiler heating surface absorbs the heat—empty pockets in setting lose heat. There are no empty pockets in this boiler.

5th—The steel-cased settings are always tight. No cracked, warped, leaky, defective and unsightly settings exist with this setting.

6th—A steel-cased setting is a simple and sure cure for air infiltration losses. The largest preventable losses we have to contend with in boiler efficiency are excess air losses.

7th—A very long gas travel—hence long contact with heating surface is provided—hence heat absorption is assured.

The "**WICKES**" boilers are boilers that engineers and business men are, more and more, not merely thinking about and considering—but, **Purchasing**—for good and *profitable* reasons!

Let us send you intensely vital reasons and facts—they will interest you.

Ask for Full Description—Sent Free.

The Wickes Boiler Company

Main Office and Works, SAGINAW, MICH. *Sales offices in principal cities*

Murphy Automatic Smokeless Furnaces

Power Plants

that are equipped with Murphy Furnaces are operating at lower cost than others, because although getting more power they are

BURNING CHEAPER FUEL
and Saving in Many Ways

Murphy Furnaces are adaptable to any kind and any size of boiler—are automatic in all their functions—handle efficiently heavy overloads with minimum attention — and are practically smokeless

The Murphy Catalog has started many a power plant toward big savings. Get your copy today

Murphy Iron Works Detroit-Michigan

178 **New York** **Chicago** **Buffalo**

Digitized by Google

Young William F. De Quincy Brown
A well-behaved from Boston town
Declared with all his main and might
That come what would, he'd be polite.

At Boston Tech the Registrar said:
"Tell me what your courses are."
And Bill politely said "I'm here
To be a Civil Engineer."

* * *

THOSE GOGGLES AGAIN.

He couldn't play football at all
At Tennis he served like a petrified man
At baseball or cricket or kicking the wicket
His athletic prowess went flash in the pan.

Scholastically he was a dub.
He couldn't tell izzard from Magdalene Bay.
He never would study and said it was "Bloody
That bloomin' old faculties hindered his play."

But still he got by like a top.
I found out the why and the wherefore at last:
He wore to his classes those tortoise shell glasses
What prof would have courage to mark him "not passed?"

* * *

THE REASON.

My Roman striped shirts are of filmiest silk
My Russian calf shoes cost a bushel of dollars
My new English overcoat forced me to bilk
My dad of a fortune, but he never hollers—
He's deaf and dumb, poor dad.

My imported scarfs and cravats are the best.
—Than a cobweb no thicker—
My hose? Cloth of gold
My tweeds and my dress clothes match up with the rest
Mamma pays for these, and she isn't a kicker—
Both her legs were amputated, poor girl.

THE TALE OF THE WUMPUS.

There once was a pop-eyed and squidgy young wumpus
Who rarely would laugh and was ne'er seen to smile
He was calm as could be and would shun any rumpus
There was not such a wumpus in many a mile.

At college (where every young wumpus is sent), he
Adhered to the teachings his father had taught.
But soon, since his kale came in bunches and plenty,
He purchased some things that he never had bought.

He was pop-eyed, I said, so he purchased some glasses
With tortoise shell rims, so his eyes ceased to pop.
He purchased a Saxon and drove it to classes
This wumpus was sowing a peach of a crop.

He smoked cigarettes and was seen drinking liquor
He mastered the difficult science of draw
His eye when he looked at a girl wouldn't flicker
His father was "dad"—and he used to be "paw."

He took up sorority fussing, in madness,
They tamed him so well he would sit up and beg
Jump through or roll over, or bark out of gladness
He fussed while his cronies were kidding the keg.

The worst of it was that he thought they were peaches
And pipins and la-las and lu-lus and such
The tales that they tell of his conquests are screeches
This wumpus was always and ever in dutch.

Digitized by Google

The Ann Arbor Savings Bank

ANN ARBOR, MICHIGAN

Capital, $300,000 Surplus and Profits, $140,000

Resources, over $3,000,000

A General Banking Business Transacted

Temple Theatre

High-Class Pictures

Down Town on Main Street **S. C. KNAPP, Prop.**

DAINES & NICKELS

PHOTOGRAPHERS

Specialize Interior, Construction and Structural Iron Work

Lantern Slides ***Enlarging and Copying***

WELCOME

To this Store's Christmas Shopping Conveniences

Mack & Co

Martha Washington and Nylo Chocolates

(EXCLUSIVE AGENCY)

LARGE SIZES FOR CHRISTMAS

University Ave. Pharmacy

Corner Church and South University **One Block from Engineering Bldg.**

Phone 416 **We Deliver**

Digitized by Google

He'd lived all his life on the farm, was the pity
And things from the country appealed to him yet
And not having met a real squab from the city
The co-edic stuff was his very best bet.

He got his deserts in a horrible fashion
Oh listen, ye wumpuses, listen and dread
He yielded one spring to loves undying passion
And stumbled and fell and went out of his head.

They lived ever after, contented and happy
As neither knew better it served 'em both right
For he had the kale if he wasn't so snappy
And she wears her pin on her dress day and night.

* * *

THERE ARE MANY SUCH.

C. E.—Why couldn't he make an engineering society?

M. E.—He couldn't get enough men together.

ERRATA.

In the article on "A Graphical Solution of Differential Equations of the First Order" in the October issue by T. R. Running, make the following corrections:

Page 119, line 1, for The, read A.
Page 119, line 19, for derivation, read a derivative.
Page 119, line 4 from bottom, for $h^{3.2}$, read $11h^{6.5}$.
Page 120, line 2, for in flow, read inflow.
Page 120, line 4, for in flow, read inflow.
Page 120, line 5 from bottom, for $f(x\,y)$, read $f(x, y)$.
Page 121, line 5, for $f(x\,y)$, read $f(x, y)$.
Page 121, line 6, for $f(x\,y)$, read $f(x, y)$.
Page 121, line 7, for $F(x\,y)$, read $F(x.\,y)$.
Page 121, at beginning of line 8, insert at.
Page 123, line 11, for obscissa x_6, read abscissa, x_6.
Page 123, line 12, for curve, the, read curve. The.
Page 123, line 13, for hP_6, read P_6.
Page 124, line 10 from bottom, for where, read when.

Digitized by Google

Michigan's Best Book Store

WAHR'S

Established for over half a century

ENGINEERING SUPPLIES A SPECIALTY

Every year sees our business increased tremendously. The reason is this:

FIRST—Because we carry the largest stock of Scientific and Technical books in the State.

SECOND—Because our stock of Drafting Instruments and Engineering supplies is always complete.

THIRD—Because we are better prepared than ever to fill your orders for books and engineering supplies.

FOURTH—Because we sell at the lowest existing prices, and will not be undersold.

PROMPT SERVICE **TRY US**

GEORGE WAHR

Bookseller and Publisher to the University of Michigan

Main and State Sts., Ann Arbor, Midh. **Send us your mail orders**

Important Information for the Practical and Student Engineer

We can furnish copies of any of the *Michigan Technics* that have ever been published, for 25c each. Separately bound copies of the series of articles by Prof. S. J. Zowski on the "Theory of Water Turbine," 50c each.

In writing please give date of issue you wish and mention name of article.

Address—

THE MICHIGAN TECHNIC

212-214 New Engineering Building Ann Arbor, Michigan

Rentschler's

Studio

Portrait

Photographer

319 E. HURON ST. **PHONE 961 M**

Digitized by Google

UNIVERSITY OF MICHIGAN

DEPARTMENT OF ENGINEERING

Civil Engineering
Mechanical Engineering
Chemical Engineering
Electrical Engineering
Marine Engineering and
Naval Architecture

DEPARTMENT OF ARCHITECTURE

Architecture
Architectural Engineering

Extensive and well equipped laboratories and shops. Opportunity for specialization in the various branches of engineering and architecture.

Study for advanced degrees in engineering and architecture pursued in the graduate department of the University.

Technical instruction by men of professional experience. Forty assistants at salaries of from $50 to $600, appointed annually from the graduate and senior students.

Students in Engineering and Architecture may take any work and enjoy any of the pribileges in the Department of Literature, Science, and the Arts, the same as if students in that Department.

For the University Calendar, address

SHIRLEY W. SMITH, Secretary.

For copies of the Announcement of the Departments of Engineering and Architecture and for special information, address

JAMES P. BIRD, Secretary
Ann Arbor, Michigan

THE ANN ARBOR PRESS—PRINTERS

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

JUN 2 3 1920

Digitized by Google